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Technological Innovations in Japan and S&T Experiences in the Philippines: Drawing Policy Lessons for the Philippines

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I

Introduction

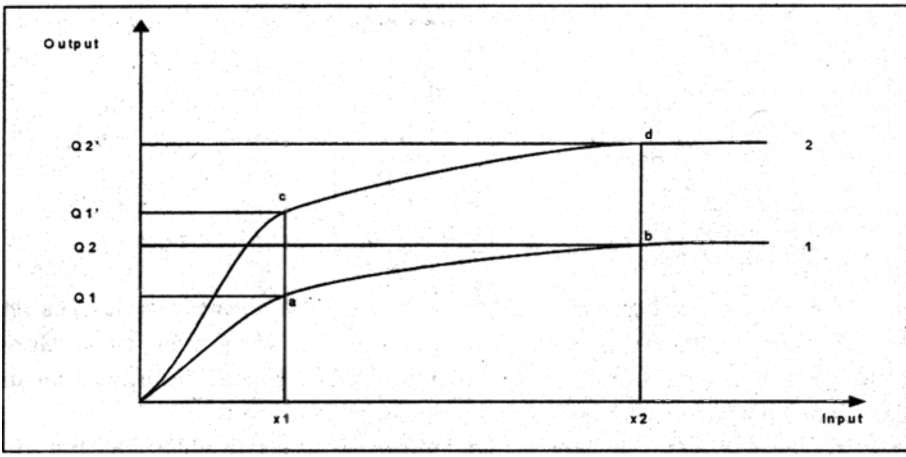
Economic growth is determined by how well a country mobilizes its resources in order to increase the production of goods and services. Generally, resources include labor and human skills, capital, land, and natural resources.

There are two approaches to economic growth (Choi 1983). One approach is to increase the utilization or the amount of factor inputs or resources for production. For example, output from agriculture can be expanded by increasing the utilization of available arable land that had been previously considered idle for farming. One drawback to this approach is that if one keeps on increasing the amount of the same factor inputs into the production process, the increase in the level of output that can be generated will eventually be subject to diminishing returns. Stated graphically in a production function, output increases rapidly at the initial stage (around point *a* in Figure 1). However, if one keeps on adding the amount of the same factor input, the increase in output that may be generated may not be as much as in the initial stage (movement toward point *b* along production function 1).

Krugman (1995), in a highly controversial paper titled "The Myth of Asia's Miracles," argues that Singapore's rapid growth was due to capital accumulation, and certainly not a "miracle." Its growth path is similar to the capital accumulation type of growth of the Soviet Union that first experienced rapid growth during the 1950s and then suffered a significant economic slowdown once it reached its limits. "Economic growth that is based on expansion of inputs, rather than on the growth of output per unit of input, is inevitably subject to diminishing returns."

This leads to the second approach that deals with improved productivity through a more efficient utilization of the same amount of inputs. Stated graphically, this means an outward shift in the production function (from 1 to 2 in Figure 1). Thus in this shifted production function, for every level of

Figure 1. Production Function



factor input, there is a corresponding higher level of output, indicating a higher productivity of output per unit of input (from point a to point c, and from point b to d). The productivity improvement could largely be due to the introduction of the process of technological innovation in production. As we shall discuss below, this process of technological innovation could involve a range of activities. For example, it could involve the utilization of better machinery, better production management and methods, and the application of best practices, among others. It could take place in factories or in offices.

It is important to note at this juncture that technological innovation and economic growth are mutually reinforcing (Hirono 1985). That is, higher rate of growth would tend to generate productivity improvement through technology innovation, and vice versa. This is especially true when there are increasing returns to scale. In such cases, the outward shift of the production function would have no boundaries, implying that there would be no limits to growth.

Historically, the whole idea of technology affecting economic growth dates back to the eighteenth and nineteenth centuries, when scientific principles, which were accumulated since the start of modern science in the sixteenth and seventeenth centuries, were turned into technologies and applied to production during the industrial revolution in western Europe. The steam engine, for example, which triggered the industrial revolution, was the result of the accumulation of knowledge through scientific discoveries and the application to production.

However, the relationships between technological innovation and economic growth were made evident by the remarkable experiences of Japan after World War II and South Korea in the 1960s or after the Korean War. Through technological development policies that started to turn the wheel of technological innovation, these countries were able to achieve rapid economic growth in a sustained manner. In a significantly shorter period of time compared to the development in western Europe, these countries were able to transform their economies from being almost completely devastated right after the war to being highly advanced industrial economies at present.

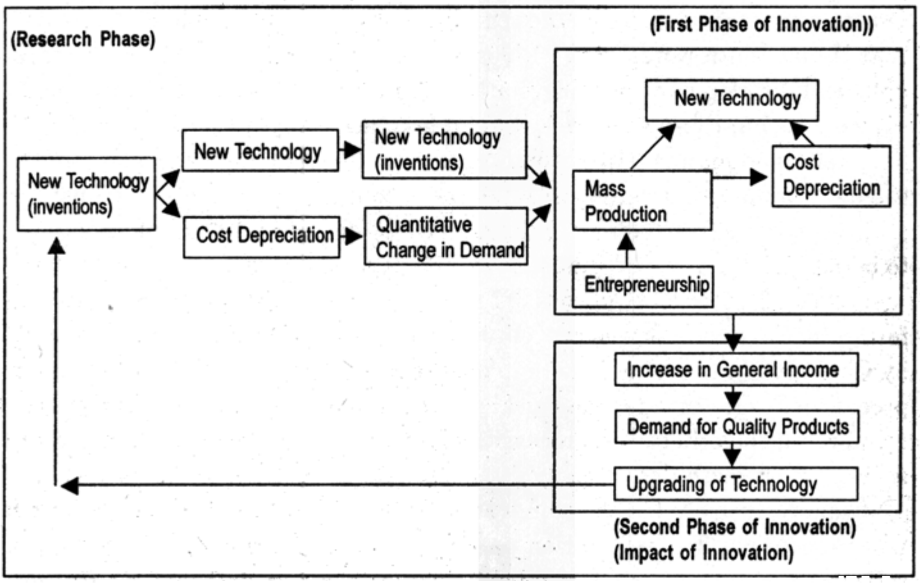
Figure 2 shows the process of technological innovation that is being referred to. This process was conceptualized by Yamada (1964) and later cited by Choi (1983). It is shown here to emphasize the point that it is a dynamic process of progressive technological advances and economic growth, each one reinforcing the other. The process continues in a sustained manner, and in each round growth improves.

Generally, technological innovation involves two major parts—research and innovation. The innovation part has two phases. In the first part, the introduction of new technology leads to new products and reduces the cost of production. These new products have better quality than before. Because of the reduction in cost per unit, for the same total cost of production, the quantity of output that could be produced would increase. Better-quality products and greater volume of production result in mass production that attracts entrepreneurs to increase their marketing effort and further reduces cost because of economies of scale. Mass production and lower cost could result in mass consumption. This whole set of activities could lead to improved income for the general public, which in turn. could lead to changes in taste, thus creating higher demand for more quality products. This impulse triggers off pressure to improve the existing technology. Thus, the entire process repeats itself continually toward economic prosperity.

The performance of Japan and South Korea is indeed outstanding. They have been able to close their technological gap with highly advanced industrial countries in so short a time. From the perspective of developing countries, the question to ask is: Can this fast- catching up process generally hold for the rest of technologically backward developing countries?

There are two schools of thought on this issue that ought to be reviewed briefly because of their implications to the Philippines case.

Figure 2. Technological Innovation Process



Source: Quoted from Choi (1983); original source is Yamada (1964)

The first school,[1] which started with Gerschenkron's (1962) discussion of the advantages of backwardness, deals with the issue of convergence (Barro and Sala-i-Martin 1995). The convergence school states that technologically backward countries benefit from the technology created by advanced countries. One of the strongest postulates of this school categorically states that the "catch-up growth is proportional to the difference in technological capabilities between a follower and the leaders. This predicts an inverse relationship between technological capabilities at any point in time and subsequent productivity (as well as economic) growth" (Evenson and Westphal 1995).

Through technology transfer, backward countries can catch up with advanced nations. With appropriate policies and investments on education, physical capital, general management capability, and research and development (R&D), backward countries can learn the technology developed in advanced nations. Alongside these developments is a convergence of income and productivity levels.

The paper of Evenson and Westphal (1995) provides a good survey of literature on this issue.

The other school argues that the process may not be that easy and straightforward. Although newly industrialized countries (NICs)[2] have grown rapidly in recent times and have in fact converged to the leading countries in terms of income and productivity, most developing countries are not on a similar path of convergence toward advanced nations. In fact, there is a divergence (Williamson 1991). A whole range of factors may be responsible for the divergence and the widening gap between most developing countries and advanced nations. These factors can include adverse institutions and deficient policy regimes. Among others, Choi (1983) points to the vicious circle of poverty in which most developing countries are trapped. He cites other factors:

1. Developing countries are weak in policy formulation for scientific and technological development. In these countries, public interest in science and development is low. Their traditional cultures are hostile and can pose hindrances to the creation of viable science policy.
2. Viable institutional setups are lacking and R&D systems are inadequate in these countries. Often, research equipment are inadequate, research budgets are nil, and research budget allocation is extremely inefficient.
3. There is very limited scientific manpower in these countries.
4. Most of these countries rely heavily on imported technology. Still, there are no clear-cut policies and programs to develop domestic capability to modify and improve imported technologies for local applications. There are no policies to address technological dependence.
5. Also lacking in these economies is the participation of relevant sectors in the development of science and technology (S&T), particularly in the industrial sector to which most of the applied research and development efforts are directed.

Still another point that has bearing on the discussion of the Philippine case relates to industrial strategy and the role of government. The issue is relevant in the present context for the following reasons: (a) countries which have performed remarkably well like Japan[3] and South Korea have applied industrial strategy that largely centered on technological development and with extremely strong government leadership; and (b) industrial strategy with strong government intervention seems inappropriate in a "globalized" world market.[4]

[2] Generally known to include South Korea, Hong Kong, Singapore, and Taiwan.

[3] Whose experience the paper will heavily draw policy lessons from for the Philippines.

[4] The ongoing economic reforms in the Philippines are largely premised on a free-trade world environment.

There are two schools of thought that are worthy of review.[5] One is based on the argument of the neoclassical school, which centers on neutral government policy, while the other is based on industrial strategists' idea of selective intervention by government to manage technological change aimed to achieve a dynamically efficient industrialization.

According to the neoclassical school, the role of the government is simply to provide an economic environment in which market forces will realize the efficient allocation of resources. If there are market failures, then the appropriate policy instruments are prices and price-denominated policies (e.g., taxes and subsidies), which have to be applied fairly. If institutions are lacking, then the government's proper role is only to facilitate the establishment of such institutions that should function as market agents. If social overheads are too large and expensive for the private sector to undertake, then the government can assist, without necessarily promoting specific industrial activities. The neoclassical advocates support human capital formation, but only in ways that do not discriminate against other activities.

According to the other school, "market forces *alone* are not responsible for the purported market success of economies like Japan and Korea. Neutral policy regime is not a necessary condition for successful industrialization" (Pack and Westphal 1986). Furthermore, this school states that neutral policy regime may not be a generally sufficient condition for rapid industrialization that is based on technological change. This is because acquisition of technological capability happens neither automatically nor without cost. The key elements of technology are often imperfectly traded, or worse, in a great number of cases, not at all. As we have discussed above, there are many institutional bottlenecks other than poverty that may hinder the growth of science and technology in these countries. All these factors provide stumbling blocks to the growth of these countries, especially in terms of technological development.

This paper will attempt to look into the technological innovation experience of Japan during the early period of its rapid economic growth after World War II. Among the main issues that it will address are the initial conditions, the economic environment in which the economy was operating at the time, the goals and strategies pursued, economic policies implemented, programs developed, and the role of government. The paper will then try to contrast this experience with that of the Philippines and will attempt to draw policy lessons for the country in the light of the issues raised above.

[5] The paper of Pack and Westphal (1986), which this part heavily draws from, provides a good review on this issue.

II

Patterns of Technological Innovations in Japan

Initial Conditions

Before the war. Years before World War II broke out, Japan had already embarked on an industrial development program. In fact, heavy and chemical industries already made remarkable growth in the 1920s. By the beginning of the 1930s, these industries were at the verge of a rapid take-off (Takafusa 1994). The textile industry grew rapidly, as well as heavy industries such as steel. Another standout industry was rayon production, the production technology for which was perfected in the 1930s. In machinery, Japan became almost completely self-sufficient, except for special high-end items. This formed the basis for the development of military supply industries. During this period, exports grew rapidly also.

These developments since the 1920s allowed the Japanese to accumulate valuable experience in economic growth and technological development, which proved to be one of the major driving forces of the rapid economic growth after the war.

Industrial policies during the period such as government subsidies gave birth to a number of new industries and big corporations. These industries included electric power, electric smelting of aluminum, electronics, and automobile industries, to name a few. In fact, the origins of some of the present-day big corporations in Japan (e.g., Toyota, Toshiba, NEC, Nippon, Nissan, etc.) can be traced back to this period.

A number of important economic laws were passed and implemented during this period as well. Among the important ones that started Japan's march toward industrialization were the Oil Industry Law of 1934, the Automotive Industry Law of 1936, the Artificial Oil Industry Law and the Steel Industry Law of 1937, and the Machine Tools Industry Law and the Aircraft Manufacturing Industry Law of 1938.

A number of key economic institutions were established during the period. For example, the Cabinet Planning Board was organized in 1927. Originally, it consisted of the Planning Agency and the Resource Bureau. In 1937 the Planning Agency was reorganized and tasked to implement a Five-Year Plan for Key Industries. In 1956 the Science and Technology Agency was established. During this period, the Council for Science and Technology was also created to act as the policymaking body on science and technology at the national level. Furthermore, many national as well as industry-sponsored research institutions were founded. For example, the Tokyo Industrial Testing Laboratory and Institute of Physical and Chemical Research already existed then and were closely linked with industries.

Foundations of the postwar economy. World War II brought tremendous damage to Japan, which lost about one-fourth of its physical assets (Takafusa 1994). Table 1 shows some estimates of the extent of the damage. Despite this massive devastation, Japan was able to build up its production capacity by producing armaments. Heavy industries and chemical industries increased their plant and equipment for the production of military supplies.

According to Takafusa (1994) much of these production capacities were spared during the war. For example, steel production capacity that stood at 3 million tons in 1937 increased to 6.6 million tons during the peak of the war. After the war, Japan was left with a substantial capacity of 5.6 million tons. Similarly, copper refining, lead, and aluminum, which saw major capacity expansion during the war, were left with huge production capacity af-

Table 1. Destruction of National Wealth in Japan (billion yen)

	Total damage	Estimated value of undamaged state	National wealth remaining at war's end	Percentage of damage	National wealth in 1935 calculated at value of war's end
Gross value of national assets	64	253	189	25	187
Buildings and other structures	22	90	68	25	77
Industrial machinery	8	23	15	34	9
Ships	7	9	2	82	3
Electricity and gas supply facilities and equipment	2	15	13	11	9
Furniture and household effects	10	46	37	21	39
Production goods	8	33	25	24	24

Source: Quoted from Takafusa (1994). Original source: Economic Stabilization Board, *Taiheiyo Senso ni Yoru Wagakuni no Higai Sogo Hokokusho* (*Comprehensive Report on Damage to Our Country in the Pacific War*), 1949 ter the war. Machine tool production capacity, which stood at 22,000 units in 1937, increased to 60,000 units at the height of the war, and declined slightly to 54,000 units after the war. Thus, although Japan experienced substantial damage as a result of the war, it did not go back to square one right after the war, what with greater expertise, enhanced skills, and some production capacities intact. "The fact that the plant and equipment of heavy and chemical industries survived the war, as did their technical specialists and laborers, provided the necessary conditions for the postwar economic recovery that was centered on these industries. This is one important legacy," says Takafusa (1994).

Another important legacy of the war cited by Takafusa was the organizational structure of industry. Before the war Japan practiced subcontracting in the field of machinery, aircraft, and automobile production. The practice continued after the war, particularly among big firms. Usually, big firms do the assembly, while subcontracting firms make the materials and components. The subcontracting system serves as an important mechanism for transferring and diffusing technology, especially from bigger principal firms to smaller sub-contractor firms. In Japan 65 percent of small and medium enterprises (SMEs) produce under subcontracting arrangements. Eighty-two percent of them are found in the machinery and textile sectors. In 1981 81 percent of SMEs were in the transportation machinery sector, 88 percent of which specialized in subcontracting. In Japan subcontracting is extensive because there is less vertical integration (Nagaoka 1989). As a major feature of Japan's economic development, subcontracting has enabled the machinery sector to enjoy international competitiveness.

Subcontracting arrangements usually involve implicit contracts requiring technical guidance, labor supply, leasing of equipment, and risk sharing by a principal firm. Also, the system provides strong incentives and pressures for subcontractors to innovate. Typically, the principal firm is responsible for developing designs and specifications, and provides the necessary technical assistance to the subcontractors, who undertake the production according to the principal's requirements. This kind of arrangement is possible because subcontractors have high technical capabilities just like the principal firms.

During the war Japan began to develop financial expertise by setting up financial institutions to serve the munitions companies. It was also during this period that Japan became internationally known for its "administrative guidance." Generally, the government had the power to instruct business on various issues, directly or indirectly. For example, during the war the Bank of Japan exerted strong control over private banks.

Labor unions existed, but were dismantled during the war. However, their rebirth after the war helped improve the welfare of the labor sector, which in turn established a generally productive relationship between labor and management. Also, the social security systems (which covered health, insurance, and pension) that evolved during those years and which greatly benefited the laborers lent the necessary stability to the labor sector. Takafusa (1994) claims that these social security systems constituted one of the cornerstones of the postwar economic development in Japan.

All told, even before World War II broke out, the key ingredients for an industrial take-off were already present in Japan. Technological experience started to accumulate. Concerns for planning and for identifying key industries became major policy issues. Some key institutions were established. The government as an institution was very strong in managing the development process. Even during and right after the war, the industrial base of the economy expanded. Although the war brought a lot of damage, it left behind certain important legacies that later became key factors during the reconstruction period and the rapid economic growth era in the 1960s and 1970s.

Conditions for Rapid Growth

Table 2 shows how Japan sailed through the rapid economic growth after the war. For 15 years starting 1955, Japan's economy grew annually by 10.3 percent, more than twice the annual average growth of 4.4 percent of the rest of OECD (Organisation for Economic Co-operation and Development) countries over the same period. Even during the second half of the 1970s when the world economic environment was severely affected by the second oil crisis, Japan stood out as the fastest-growing industrial economy.

Improvement in productivity played a major role in the rapid growth of Japan after the war. Evidences of total factor productivity (TFP), computed using the growth accounting method, indicate that more than 50 percent of Japan's economic growth in the 1950s and 1960s can be attributed to TFP growth and more than 20 percent to improvement in technical knowledge. Table 3 indicates that the contribution of productivity to Japan's growth during this period was a lot higher than those of the United States, the former West Germany, France and the United Kingdom.

Table 2. Average Annual Growth Rates (%) of Real GNP of Six Major Industrial Countries

Country	1955-60	1960-65	1965-70	1970-75	1976	1977	1978	1979
France	2.0	5.8	5.8	3.9	4.6	3.0	3.0	3.5
Italy	5.6	5.3	5.9	3.8	5.7	1.7	2.0	3.5
Japan	**8.9**	**10.0**	**12.1**	**6.8**	**6.5**	**5.2**	**5.8**	**4.3**
United Kingdom	2.7	3.4	2.4	2.3	2.3	1.6	3.0	2.3
United States	2.2	4.8	3.3	2.5	5.7	4.9	3.3	2.0
West Germany	6.6	5.0	4.8	2.2	5.7	2.6	3.0	4.0

Note: GDP growth for France, Italy and United Kingdom
Source: Quoted from Hirono, 1980. Original sources: OECD, National Accounts of OECD Countries, 1955-75, and OECD, *The OECD Observer*, No. 96 January 1979, Table 2, p. 20

Another major factor that contributed to Japan's postwar growth was the high rate of capital formation that was propped up by the continuous acquisition and development of technology. As will be discussed below, this high rate of capital formation came about because of the Japanese people's high propensity to save.

A number of factors were behind the extraordinarily high economic growth in Japan. Hirono (1980) singles out five of them, namely: (a) abundant supply of well-educated and well-disciplined labor force; (b) high level of savings propensity among the households; (c) competitive spirit of major economic actors: (d) high-growth economic policies of the government under continued political stability; and (e) favorable international economic environment.

Labor force. After the war school attendance at all levels improved rapidly, thus expanding significantly the supply of better educated workforce. According to Hirono (1980) in 1945 nearly 100 percent of children between 6

Table 3. Source of Economic Growth

Measures	Japan 1953-71	USA 1948-69	W. Germany 1950-62	France 1950-62	United Kingdom 1950-62
Standardized growth rate	8.81	4.00	6.27	4.70	2.38
Total factor input	3.95	2.09	2.78	1.24	1.11
Labor	1.85	1.30	1.37	0.45	0.60
Capital	2.10	0.79	1.41	0.79	0.51
Output per unit of input (Standardized)	4.86	1.91	3.49	3.46	1.27
Advances in knowledge and others	1.97	1.19	0.87	1.51	0.79
Improved resource allocation	0.95	0.30	1.01	0.95	0.12
Economies of scale	1.94	0.42	1.61	1.00	0.36

Source: Denison and Chung, 1976

and 12 years old were enrolled in primary schools. Among those between 13 and 17 years old, 28 percent of them were in secondary schools and 5 percent in the tertiary levels. In 1960 those percentages improved to 100 percent, 74 percent, and 10 percent, respectively. In 1975 enrollment in the secondary and tertiary levels rose further to 92 percent and 24 percent, respectively.

Aside from being better educated, Japanese workers were highly disciplined, industrious, and loyal to their employers. These traits lent stability to the workplace. The stability prevailed as labor unions became stronger and labor relations improved. An institutional foundation for industrial relations was set up by the government through the passage of three pieces of legislation that provided the legislative framework for labor issues: the Labor Union Law, the Labor Standards Law, and the Labor Relations Adjustment Law.

Three basic features of employment in Japan brought about substantial improvement to the welfare of its labor: age-based seniority in wages, lifelong employment, and enterprise-based unions. Enterprise-based unions were organized at the firm or factory level and comprised blue-collar and white-collar, as well as skilled and unskilled, labor. Enterprise unions and lifetime employment reinforced the solidarity and loyalty of employees to the employers. For example, employees themselves would try to prevent labor strikes and work stoppages. During labor disputes, labor, together with the employers, would try hard to settle the disputes at once. These major factors stabilized Japanese industrial relations and merited the envy of other countries (Takafusa 1994).

High savings propensity. At the time when personal income was still at low levels, the traditional concept of savings as a virtue of life resulted in high rates of savings among households (Hirono 1980). Household savings were channeled to the banking and life insurance institutions, which in turn financed projects both in the private and public sectors. Gross capital formation increased dramatically as a result, increasing productive capacity and economic infrastructure. Table 4 below shows how savings and capital improved after the war. From a savings propensity of 0.09 in 1955, it improved to 0.23 in 1977. Likewise, from an investment rate of 26.2 percent in 1955, it peaked to 35.8 percent in 1972, but declined marginally to 31.2 percent in 1977.

Competitive spirit. One of the major reforms enforced by the Americans during their six and a half years of occupation of Japan after the war was the promotion of democratic forces to develop organizations in labor, industry, and agriculture. A major part of this process was the liquidation of the zaibatsu and the dissolution of the large industrial and banking institutions. The four major zaibatsu—Mitsui, Mitsubishi, Sumitomo, and Yasuda—were dismantled and restructured. For example, the holding company of Mitsui that held the stocks of its subsidiaries was dissolved while the stocks held by the parent company were transferred to the subsidiaries. The same thing happened to the other three and the smaller zaibatsu.

Consistent with this reform was the enactment of the Anti-Monopoly Law in 1947. It prohibited the formation of trust, all cartel activities, joining of international cartels, crossholding of directorships, and even stockholding by corporations (Takafusa 1994). However, in 1949 the bans on participation in international cartels and corporate stockholding were lifted because they were believed to hinder the flow of foreign investment into Japan.

The Anti-Monopoly Law was followed by the introduction of a policy designed to eliminate the excessive concentration of economic power in the hands of a few companies. Table 5 shows the impact of this policy on industry concentration ratios. Except for food processing, concentration ratios of industries went down, indicating the entry of more firms.

Competition policy is relevant in technological development because it increases the pace of technological changes in production methods and processes, product development, raw material use, factor substitution, and management know-how. Furthermore, competition puts pressure on cost reduction and improvement in factor productivity, particularly labor productivity that can be shared by labor itself as well as by all stakeholders. However, in

Table 4. Savings and Investment in Japan

Year	Savings Propensity[1]	Investment Rate[2]
1955	0.09	26.2
1960	0.16	38.7
1965	0.17	27.9
1970	0.2	35.5
1972	0.22	35.8
1974	0.24	33.3
1975	0.23	32.7
1977	0.23	31.2

Source: Hirono, 1980.
Notes: (1) savings propensity for worker household; (2) gross capital formation as percent of gross national expenditure computed using 1975 prices

Table 5. Trends in Concentration Ratios for the Top Ten Firms in the Manufacturing Sector of Japan, by Industry Groups*

	Food processing	Textile, pulp and paper	Chemicals petroleum and ceramics	Metals and metal products	Machinery	All manufacturing
1950	100.0	100.0	100.0	100.0	100.0	100.0
1952	104.7	82.7	99.5	97.9	89.9	97.6
1954	106.7	73.4	98.9	98.0	84.6	96.3
1955	106.7	69.0	98.3	99.5	91.9	96.4
1957	110.5	65.9	93.6	98.1	87.7	94.8
1959	115.3	63.0	92.3	99.3	85.3	95.2
1960	119.7	62.9	90.6	98.7	83.1	95.5
1962	124.9	62.7	89.4	99.5	90.2	97.1
1964	123.7	64.7	89.1	98.7	97.5	97.4
1965	126.2	63.0	89.0	98.9	99.7	98.0

Source: Hirono (1980). Original sources: Fair Trade Commission, Nihon no Sangyo Shuchu (Concentration in Japanese Industries), 1963-66 and 1979

*Note: 43 industries are selected for the five industry groups; 11 for the food processing, six for the textiles; pulp and paper; 15 for chemicals, petroleum, and ceramics; eight for he metals and metal products; and three for machinery groups. The concentration ratios are computed on the basis of output rather than sales, assets or employees

the case of Japan, while the goal was to maintain competition within industry, government competition policies, which used to be very rigid in the 1940s and 1950s on cartel arrangements, changed through time in response to the changing structure and requirements of industries. Government competition policies in particular allowed differences in factor intensity across industries and took into consideration pressures from foreign competition brought about by its export orientation. By the very nature of the production process involved in iron and steel and other heavy and chemical industries, which were capital-intensive, and given the risks involved in the introduction of new technologies into these industries, some degree of cartel arrangements was eventually allowed with government support, particularly during economic downswings. Also, mergers were permitted, especially those which took place in iron and steel, automotive, ship building, and bank industries, to strengthen their competitiveness in the international markets. However, according to Hirono (1980), in spite of these changes in government competition policies, a consistent improvement in labor productivity was observed during the period. He says: "While the Fair Trade Commission has been continuously active in implementing the anti-monopoly legislation ever since its founding, it is not an unfair statement that the government's competition policy has undergone some significant modifications during the last thirty years. Whether the changes observed in government competition policy have reduced effective competition in Japanese industries or not is certainly a matter requiring serious study. One thing, however, is true—that in spite of such changes in the government's competition policy there has been a consistent rise in the level of labor productivity in the Japanese industry." This shows that the objective of increasing labor productivity was achieved even though cartel arrangements, mergers, and the like were re-introduced into the system. This may be partly due to the government's strong presence or guidance in the system.

Growth policies. A more detailed treatment of economic growth policies in Japan is provided in the section on government policies. However, generally, it was widely observed that implemented policies were formulated to achieve several objectives. One of these was to restore the Japanese economy to prewar economic growth level right after the war and to double the national income. In the National Income-Doubling Plan, for example, the government sought to double either the real gross national expenditure or the real gross national product within the decade (Takafusa 1994). According to Hirono (1980) "all the monetary, fiscal and specific policy measures available to the government were mobilized to increase the national output. The other objectives were to modernize production facilities; expand exports; enable foreign exchange earnings to ensure a continued supply of energy and raw materials required for expanded production at home; facilitate the inflow of advanced foreign technology and management know-how; improve the level of domestic absorptive capacity towards an effective utilization and development of new scientific knowledge and technologies; expand and improve the economic and social infrastructure, including transport, communications, and power network to reduce the cost of production and distribution per unit of output and throughput; and enable banking and other financial institutions to assist manufacturing and other corporations to expand capital investment." All these, together with the nationwide consensus to build a national wealth, resulted in the growth miracle during the postwar period.

Favorable international environment. The international climate during the period was highly favorable. Between 1950 and 1965, the world economic growth was impressively high, moving at an unprecedented average growth of 5 percent under the Bretton Woods system and the General Agreement on Tariffs and Trade (GATT) institution. Table 6 shows the growth of exports of Japan and the other six OECD countries during the period. These countries enjoyed high rates of growth in exports, resulting in substantial increases in the export share vis-à-vis their respective gross national expenditures.

This favorable international environment contributed to the steady export growth of Japan. Also, as the world economic progressed, the supply of materials became abundant, which allowed Japan to increase imports of its raw material requirements. During this period, Japan enjoyed favorable terms of trade as export prices were high and prices of crude oil and other raw materials were on the declining trend. In terms of volume of major export items of Japan, Table 7 indicates substantial improvement in chemical products, metal and metal products, and machinery. Incidentally, these were the industry focus in the early postwar growth strategy of Japan, in which both production and technological capabilities substantially improved.

In the financial sector, Table 8 shows substantial amounts of foreign capital that flowed into Japan to help domestic savings finance huge investment requirements. These inflows consisted of direct investment, portfolio investment, bank loans, and bonds. From US$3.2 million in 1950 capital inflow increased substantially to almost US$6 billion in 1977.

Patterns of Growth

Behind this rapid economic growth in Japan after the war was the massive transformation of its economic structure. One clear indication of the trans-

Table 6. Average Annual Growth of Exports and Exports as Percent of GNE of Six Major Industrial Countries[1]

	Average Annual Growth Rate					Exports as Percent of GNE			
	1950-60	1960-70	1965-70	1970-76	1960	1963	1970	1975	1976
France	6.4	7.6		11.7	15.0	13.0	16.0	20.0	20.0
Italy	10.5	13.4		2.7	15.0	15.0	19.0	25.0	25.0
Japan	**15.9**	**17.2**	**18.0**	**14.3**	**11.0**	**9.0**	**11.0**	**13.0**	**14.0**
United Kingdom	4.8	3.0		0.6	21.0	20.0	23.0	27.0	29.0
United States	5.1	5.7	9.4	5.6	5.0	5.0	6.0	9.0	8.0
West Germany	16.6	12.6		15.1	19.0	18.0	21.0	25.0	26.0

Source: Hirono (1980), Original source: United Nations, *UN Yearbook of Statistics, 1977* and IBRD, *World Development Report*, 1978

[1]Growth rates of exports are in real terms, whereas exports as percent of GNE (gross national expenditure) are calculated on the basis of current market prices.

Table 7. Quantum Indexes of Exports of Japan, by Major Commodity Groups

Year	Textile Total	Chemical products	Nonmetallic products	products	Metals	Metal products	Machinery	Misc.
1965	31.0	67.9	26.1	89.3	33.1	46.5	18.9	52.2
1970	62.5	95.5	73.2	101.7	61.7	85.7	49.7	96.5
1972	79.8	108.6	105.9	109.2	74.3	104.3	70.4	91.8
1974	99.7	95.8	95.3	93.3	113.2	103.9	94.8	103.9
1975	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
1977	132.9	115.7	117.0	131.4	121.1	138.7	143.3	133.2

Source: Hirono (1980). Original source: Bureau of Customs, Ministry of Finance, Foreign Trade Statistics, 1979

Table 8. Long-Term Foreign Capital into Japan (million US dollars)[1]

Year	Direct investment	Portfolio investment	Bank loans and bonds	Total inflows
1950	2.6	0.6		3.2
1952	7.2	3.0	34.6	44.8
1954	2.5	1.5	15.3	19.3
1955	2.3	2.8	47.1	71.5
1957	7.3	4.2	124.1	135.6
1959	14.6	12.5	127.9	155.0
1960	31.6	42.5	137.5	211.6
1962	22.6	142.1	514.2	678.9
1964	30.6	54.2	827.9	912.7
1965	44.6	38.7	445.1	528.4
1967	29.8	130.0	687.9	847.7
1972	135.9	3,894.5	1,180.7	5,211.1
1974	133.7	1,455.5	2,304.3	3,893.5
1975	141.8	3,361.3	3,429.0	6,932.1
1977	192.6	3,028.6	2,744.1	5,965.3

Source: Hirono (1980), Original Source: MOF, Monthly Report on Financial Statistics, in EPA, Summary, 1969 and 1979

[1]On approval basis

formation was the movement of labor across sectors. Table 9a and Figure 3 show how labor in Japan had moved sectorally since the war. In 1948 farmers accounted for almost 46 percent of the total employment. The self-employed accounted for 17 percent, while employees accounted for 37 percent of the total employment. In 1963 the share of farmers went down to just 26

Table 9a. Labor Movement in Japan

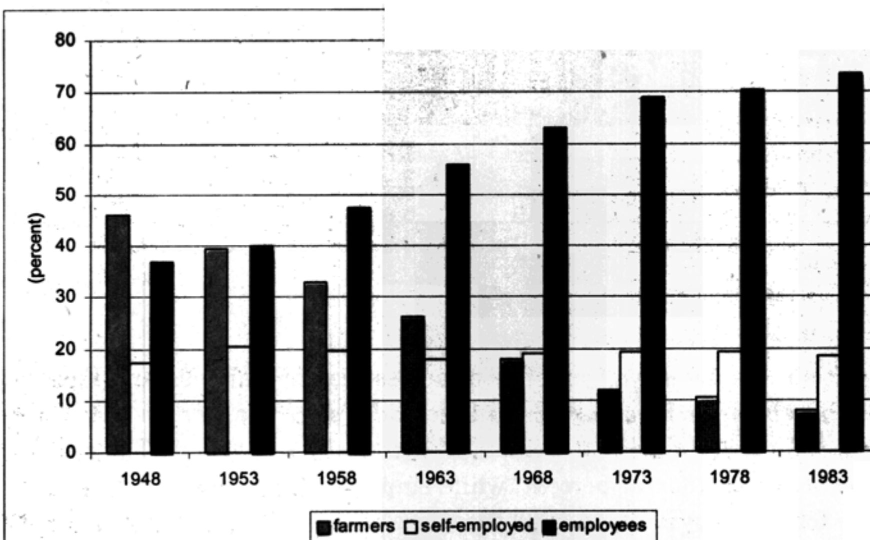
	(10,000)				Percentage Distribution (%)			
	Farmers	Self-Employed	Employees	Total	Farmers	Self-Employed	Employees	Total
1948	1,586	598	1,274	3,458	45.9	17.3	36.8	100.0
1953	1,558	807	1,572	3,937	39.6	20.5	39.9	100.0
1958	1,422	850	2,050	4,322	32.9	19.7	47.4	100.0
1963	1,201	830	2,577	4,608	26.1	18.0	55.9	100.0
1968	900	950	3,148	4,998	18.0	19.0	63.0	100.0
1973	628	1,008	3,614	5,250	12.0	19.2	68.8	100.0
1978	560	1,041	3,800	5,401	10.4	19.3	70.4	100.0
1983	453	1,059	4,208	5,720	7.9	18.5	73.6	100.0

Source: Takafusa, 1994. Original Source: Labor Force Survey

Note: Farmers - self-employed operators of farms or forestry businesses and family-member employees

Self-employed - self-employed operators on nonfarming or forestry businesses and family-member employees

Figure 3. Labor Movement in Japan



percent. While the self-employed more or less retained their share, employees increased their share to almost 56 percent. In 1983 the share of farmers dropped to just 8 percent. The share of the self-employed did not change much, but the share of employees shot up to almost 74 percent.

In terms of labor movement across major sectors, there was a clear movement to the secondary sector (particularly manufacturing) and to the tertiary sector (particularly, wholesale and retail trade sector). The employment share of the secondary sector improved from 23.5 percent in 1955 to 35.2 percent in 1977 (Table 9b). Over the same period, the share of manufacturing employment increased from 17.6 percent to 25.9 percent. On the other hand, employment in the tertiary sector (or the services sector) improved from 35.5 percent in 1955 to 53.3 percent in 1977.

The labor movement away from the farms did not adversely affect the production output of agriculture. In fact, the introduction of technology into agriculture and the successful land reform program of the government contributed substantially to the improvement of agricultural production. This was especially true in the northern part of Japan in terms of rice production. Takafusa (1994) cites the case of Tohoku region. During the prewar days, the region was producing only 30 kilos per hectare. After the introduction of better agricultural technology, its production improved to 45 to 60 kilos per hectare.

Through time productivity improved significantly. Table 10 shows that the man-hours spent on rice production declined significantly from 196 per 10 acres in 1952 to 75 in 1977. The yield, however, improved considerably from 325 kilogram per 10 acres to 455 over the same period. The factors behind this improved rice productivity included the (1) breeding of improved strains of rice; (2) increased fertilizer production; (3) rational application of fertilizer; (4) spread of new agricultural chemicals; and (5) development of technology for early planting (White Papers of Japan 1979-1980).

A closer look at the pattern of manufacturing growth in Japan is essential in understanding the dynamics of the industrialization process, as well as the technological development, during the postwar period. Through an industrial policy the development process focused initially on a few key industries. Through time, as the process progressed, the focus shifted to other industries.

Table 9b. Employment in Japan, by Major Sectors

	Thousands of Persons						Percentage Distribution (%)					
	1955	1960	1965	1970	1975	1977	1955	1960	1965	1970	1975	1977
Primary sector	16,111	14,240	11,738	10,060	7,354	6,137	41.0	32.6	24.6	19.3	13.8	11.5
Secondary sector	9,220	12,762	15,242	17,651	18,098	18,697	23.5	29.2	32.0	33.9	34.1	35.2
Manufacturing	6,902	9,542	11,507	13,442	13,236	13,797	17.6	21.8	24.2	25.8	24.9	25.9
Construction	1,783	2,679	3,403	3,993	4,729	4,772	4.5	6.1	7.1	7.7	8.9	9.0
Tertiary sector	13,930	16,717	20,653	24,325	27,689	28,343	35.5	38.2	43.4	46.7	52.1	53.3
Wholesale and trade	5,473	6,910	8,563	10,014	11,381	11,622	13.9	15.8	18.0	19.2	21.4	21.9
Total	**39,261**	**43,719**	**47,633**	**52,036**	**53,141**	**53,177**	**100.0**	**100.0**	**100.0**	**100.0**	**100.0**	**100.0**

Source: Hirono, 1980. Orginal source: BS/OPM, *Population Census*, in EPA, Summary, 1979, and BS/OPM, *Japan Statistical Yearbook*, 1978

Table 10. Improvement in Paddy Rice Productivity

	Man-hours per 10 acres	Yield (kg) per 10 acres
1952	196	325
1956	195	325
1960	174	368
1965	141	400
1970	121	431
1975	80	450
1977	75	455

Source: White Papers of Japan, 1979-80

Right after the war, policies focused on resurrecting and rationalizing four key manufacturing industries: electric power, steel, marine, transportation, and coal (Takafusa 1994). Meanwhile, the period witnessed the implementation of a policy to substitute coal for petroleum as the major source of energy during the mid-1950s (Hirono 1980). This substitution gave birth to the petrochemical industry, which, incidentally, provided a window of opportunity for many advanced technologies developed abroad to enter Japan. These technologies diffused to other related industries and created the favorable ripple effects. In fact, the rapid pace of plant and equipment investment in the iron, steel, and petrochemical manufacturing industries during the 1960s changed tremendously the manufacturing landscape (Hirono 1980).

It is worth noting at this point that the increasing shares of machinery, electrical, and transportation equipment, and iron and metal products in production from 1955 to 1977 were indicative of the policy focus during the period. Machinery, electrical, and transportation equipment improved their collective share in the total manufacturing production from 20 percent in 1955 to almost 40 percent in 1977, while the share of iron and metal products rose from 12 percent to 14 percent (Table 11). As a result of the growth of the manufacturing sector, the structure of the overall economy underwent substantial changes during the period. The share of the primary sector went down from 18.5 percent in 1995 to just 4.9 percent in 1977. The secondary sector's share increased from 34.7 percent in 1955 to 42.9 percent in 1970 (Table 12). However, brought about by the recessionary effects in the mid-1970s, the share of the manufacturing sector dropped in 1975, only to recover later on. Meanwhile, the share of the tertiary sector continued to surge during the period.

Favorable international environment and improved productivity in heavy and chemical industries as a result of government's focus on these industries increased the international competitiveness of Japanese products, thus improving the country's export performance considerably. During this period changes in the structure of exports took place. In 1955 exports from heavy and chemical industries accounted for 38 percent, while exports from light industries accounted for 52 percent (Table 13). In a span of two decades, the structure changed dramatically, with exports from heavy and chemical industries capturing about 85 percent and those from light industries 12.5 percent.

Table 11. Structure of Manufacturing Sector

	Trillion yen, current prices						Percentage distribution (%)					
	1955	1960	1965	1970	1975	1977	1955	1960	1965	1970	1975	1977
Food, beverage, textile, clothing	0.9	1.5	2.4	3.8	5.9	9.0	37.1	26.4	22.0	15.7	15.8	17.4
Wood, furniture, paper, printing, leather, rubber	0.4	0.6	1.3	3.4	4.8	7.4	15.0	11.1	12.2	13.7	12.7	14.4
Chemical, coal, ceramics	0.4	0.9	2.0	3.9	6.6	7.8	15.6	16.8	18.4	16.0	17.5	15.0
Iron, nonferrous, metal products	0.3	0.9	1.5	3.9	5.6	7.2	12.0	15.6	14.2	16.0	14.8	13.8
Machinery, electrical, trans. misc	0.5	1.7	3.6	9.5	14.8	20.4	20.2	30.1	33.2	38.6	39.3	39.5
Total	**2.4**	**5.5**	**10.7**	**24.6**	**37.7**	**51.8**	**100.0**	**100.0**	**100.0**	**100.0**	**100.0**	**100.0**

Source: Hirono, 1980. Original source: EPA, *Annual Report on National Accounts*, in JERC, *Showa Roku Junen no Nihon Keizai* (*Japanese Economy in 1975*), and BS/OPM, *Nihon Tokei Neukan* (*Japan Statistical Yearbook*), 1971, 1976, 1978

Table 12. Structure of Production

	Trillion yen, current prices						Percentage distribution (%)					
	1955	1960	1965	1970	1975	1977	1955	1960	1965	1970	1975	1977
Primary	1.6	2.1	3.1	4.5	8.2	9.3	18.5	12.6	9.3	5.9	5.3	4.9
Secondary	3.0	6.8	13.6	32.6	57.3	69.1	34.7	40.9	40.7	42.9	37.3	36.3
Manufacturing	2.4	5.5	10.7	26.3	37.7	52.9	27.5	33.1	32.1	34.7	24.5	27.8
Construction	0.4	1.0	2.5	5.7	13.5	15.2	5.0	6.2	7.4	7.5	8.8	8.0
Tertiary	4.0	7.8	16.8	38.9	88.4	112.1	46.8	46.5	50.1	51.2	57.4	48.8
Total	**8.6**	**16.7**	**33.5**	**76.0**	**153.9**	**190.4**	**100.0**	**100.0**	**100.0**	**100.0**	**100.0**	**100.0**

Source: Hirono, 1980. Original source: EPA, *Annual Report on National Accounts*, in JERC, *Showa Roku Junen no Nihon Keizai* (*Japanese Economy in 1975*) and BS/OPM, *Nihon Tokei Neukan* (*Japan Statistical Yearbook*), 1971, 1976,1978

Table 13. Structure of Export of Japan, by Major Commodity (percentage share)

	1955	1960	1965	1970	1975	1977
Heavy and chemical ind'l. products	38.0	44.0	62.6	72.4	83.5	85.0
Metal and metal products	19.2	13.8	20.3	19.7	19.2	14.2
Iron and steel	12.9	9.6	15.3	14.7		
Machinery	13.7	25.3	35.2	46.3	57.1	65.2
Vessels	3.9	7.1	8.8	7.3		
Chemical products	5.1	4.5	6.5	6.4	6.9	5.3
Light industry products	52.0	47.5	31.8	23.2	14.0	13.0
Textile products	37.3	30.0	18.7	12.5	5.8	5.2
Nonmetallic minerals	4.9	4.4	3.1	1.9		
Others	9.8	13.1	10.1	8.8		
Raw materials	6.8	2.2	1.5	1.0	1.1	0.9
Foodstuffs	3.2	6.3	4.1	3.4	1.4	1.1
Total	100.0	100.0	100.0	100.0	100.0	100.0

Source: Hirono, 1980. Original source: MITI, *Tasusho Hakusho* (White Paper on International Trade) in BS/OPM, *Japan Statistical Yearbook*, 1966 and 1978

Goals, Strategies and Directions

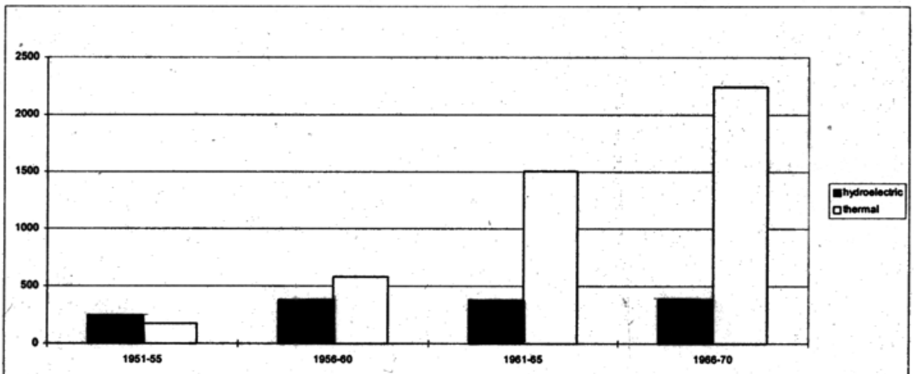
The majority of Japanese during the early part of the postwar period wanted nothing but to restore the economy to the prewar economic levels and to become a wealthy nation through industrialization. Takafusa (1994) calls this resolve a "national consensus for building a wealthy nation." This goal was clearly articulated in the National Income-Doubling Plan that was launched during the period. The Plan sought to double either the real gross national product or the real gross national expenditure of Japan within a decade. Thus, capital investments stepped up. In fact, the *White Paper on the Economy* for 1961 employed the phrase "investment breeds investment" to describe the acceleration of investment during the period.

Japan's growth strategy during the period had three major features: (1) unbalanced growth wherein key industries were selected for promotion; (2) export orientation; and (3) introduction, assimilation, and improvement of foreign advanced technology. Another very important feature of Japan's growth strategy was the "continued reliance on the part of the government and the private sector alike on the role of industrial policy in managing the long-term industrial and economic development of the nation" (Hirono 1980). Thus, the overall industrial policy utilized all government policy measures in a systematic way and in the "most appropriate combinations so that industrial development may take place in a more planned fashion, moving from lower stage to higher stage without interruption, and (so that it) may be accelerated sufficiently ahead of time when changes in demand appear at home and abroad" (Hirono 1980).

In the unbalanced growth strategy,[6] heavy industries were given more emphasis than light industries. These industries included electric power, steel, marine transportation, coal, and petrochemical. During the period, major bottlenecks were often found in the electric power industry. Electric power was in extremely short supply, resulting in regular power outages. It was therefore thought that growth could proceed only if power supplies were to be massively expanded. Figure 4 shows how power capacity considerably expanded during the period.

In the steel industry, the capacity was short and therefore had to be expanded and improved. The Ministry of International Trade and Industry (MITI)

Figure 4. Completion of Electric Power Development Projects in Japan (10,000 kilowatts)



	1951-55	1956-60	1961-65	1966-70
Hydroelectric	247	384	378	390
Thermal	174	584	1510	2246

Source: Quoted from Takafusa, 1994. Original source: *Nihon Kaihatsu Ginko Nijugonen Shi* (*A Twenty-Five-Year-History of Japan Development Bank*), 1976
Note: In addition, 10,000 kilowatts of nuclear power were completed in 1961-65 and 1,320,000 kilowatts in 1966-70.

[6] An economic approach to development first advocated by Hirshman (1958). There is also another approach called the balanced growth strategy by Nurske (1953). The unbalanced approach holds that the most important sector be given priority first because developing countries usually lack the capital necessary to develop all sectors simultaneously. Greater investments will therefore have to be poured into these selected industries only. Growth in these sectors will consequently result in increased growth in the other sectors. On the other hand, the balanced growth theory states that all sectors have to be developed simultaneously. This is because all industries are linked and interdependent. If only few industries are selected, growth will be hindered because their products would have limited markets. Market limits take place when other industries (which contribute to the overall market) are not allowed to grow as much as the key ones. Thus the unbalanced growth approach creates its own bottlenecks.

instituted two rationalization programs. The first (1951-1955) gave emphasis to the introduction of rolling processes to produce steel sheets. This was the area in which Japan was significantly behind during that period. In the second program, investment was focused on rolling processes. As a result of these programs, production capacity was boosted from 12.5 million metric tons of pig iron, 28.2 million metric tons of crude steel, and 140 million metric tons of rolled steel.

World War II wiped out almost completely the merchant marine. It therefore had to be rebuilt from scratch. A massive program was implemented to rebuild the industry. Table 14 shows how the capacity of the industry improved drastically during the period. It also shows how much government finance was made available for construction.

Since Japan at that time was heavily dependent on coal as a source of energy, the industry had to be promoted. However, at about the same period, there was a concerted effort to substitute petroleum for coal as a source of energy. It was then that the petrochemical industry started to pick up and became the window of opportunities for advanced foreign technology to flow into Japan. As a result, the industry became one of the fastest-growing industries in postwar Japan between the late 1950s and early 1970s. Petrochemical complexes were built. New technologies were imported and further developed. The growth of the industry resulted in the birth of new industries and created a flood of new technologies. It is interesting to note that it was during this period that Japan had the capacity to absorb all these technologies because of its well-trained and experienced workforce. According to

Table 14. Japan's Shipbuilding Program

	Number of vessels	Gross tons (10,000 tons)	Contract price for vessel by government (Y100 million)	Percent financed
1947-50	164	69	581	57
1951-55	159	132	1,776	44
1956-60	140	136	1,654	50
1961-65	164	449	3,129	66
1966-70	290	1,136	6,921	69

Source: Quoted from Takafusa, 1994
Original source: Nihon Kaihatsu Ginko Nijugonen Shi (A Twenty-Five-Year-History of Japan Development Bank), 1976

Takafusa (1994), "it was this latent strength that underpinned the rapid economic growth of the postwar period."

Although one of the major strategies of Japan was export orientation, this was not realized until it started to develop indigenous products and processes (Nagoaka 1989). Therefore, initially it relied heavily on the domestic market. Thus, during the early years after the war the importation and assimilation of foreign technology was associated with sales to the domestic market (i.e., either import substitution or development of a new market in the domestic market). Substantial export expansion came about only when Japan started to produce indigenous products. It took considerable technological effort, though, for newly introduced technology to generate sizeable exports.

Technological Development Strategy of Japan

There were clear shifts through time in technological emphasis in Japan. In the 1940s and 1950s, imported technologies were of prewar origin. These included the coking, vinyl chloride resin, and nylon manufacturing technologies (Hirono 1985). Once these technologies were imported, they were adapted to the needs and conditions of Japanese companies in terms of manpower, machinery, management, and money. They were also continuously improved. These developments gave rise to new industries such as those of the synthetic, chemical fiber manufacturing, and petrochemicals.

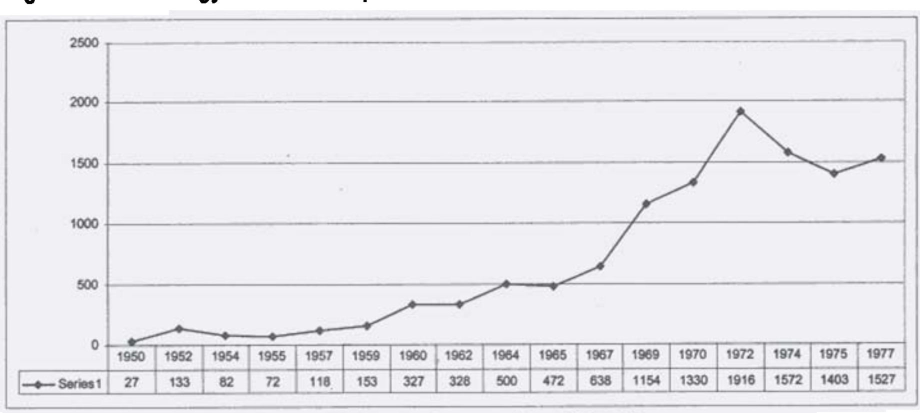
In the middle to the late 1950s, imported technologies found their way into machinery and metal production. Later, in the 1960s, the application of these technologies spread into the manufacturing of electrical machinery, general machinery, precision machinery, and shipbuilding. It was also during the 1960s when a whole range of electronic products came into existence. Furthermore, as a result of technological innovations that took place in the chemical industry in the 1950s, the iron and steel industries became modernized, boosting their production. Thus, these industries saw considerable growth within the period.

In sum, the technological development strategy of Japan supported the whole industrialization process. Japan allowed the importation of advanced foreign technologies into the industries that had been initially targeted to start the process after the war. Because of well-educated and well-trained technical and scientific manpower, these foreign technologies were absorbed adequately into the industries. Also, because of sufficient absorptive capabilities, improvements were introduced into these technologies.

Figure 5 indicates the flow of foreign technologies into Japan, which became rapid in the second half of the 1960s until it peaked in 1972. Figure 6 also shows a massive inflow of foreign technologies as payments for the flow of technical know-how surpassed significantly the receipts.

Imported advanced foreign technologies went into three major industries. From the period 1950 to 1977, chemical industries absorbed 17.5 percent of the inflow of foreign technologies (Table 15). Over the same period, machinery absorbed 25.8 percent, of which specialized machinery accounted for 15.3 percent. Electrical equipment also absorbed a sizeable share of 17.1 percent. Two important developments are worth noting here: (a) that the inflow of

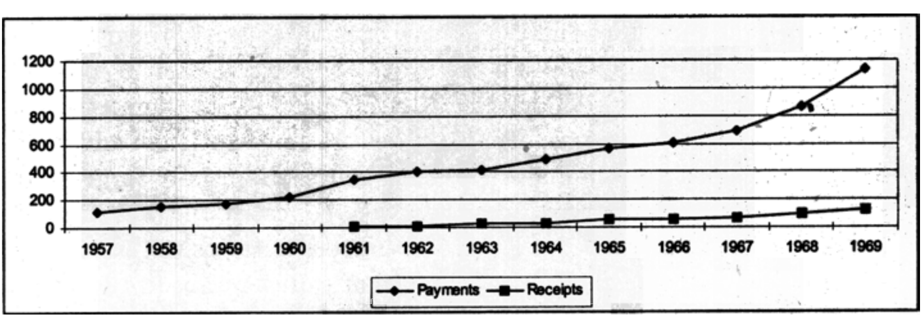
Figure 5. Technology Inflow Into Japan



	1950	1952	1954	1955	1957	1959	1960	1962	1964	1965	1967	1969	1970	1972	1974	1975	1977
Series1	27	133	82	72	118	153	327	328	500	472	638	1154	1330	1916	1572	1403	1527

Source: Hirono (1980), Original Source: MOF, Monthly Report on Financial Statistics.
Note: Technology inflows cover only those requiring royalty payment beyond one year in foreign currency.

Figure 6. Japan's Import-Export Balance of Technical Knowhow (Y100 million)



Source: White Papers of Japan, 1969-70

Table 15. Destination of Inflow of Foreign Technology into Japan, by Sector (percentage distribution, %)

Sectors	1950-70	1971	1972	1973	1974	1975	1976	1977	1950-77
Textiles	4.9	6.5	9.1	12.2	11.6	12.3	13.4	13.1	8.5
Chemicals	21.0	19.1	15.4	13.9	16.7	13.4	11.5	13.9	17.5
Fibre	0.4	0.3	0.2	0.1	0.1	0.1	0.1	0.3	0.3
Pharmaceuticals	2.9	3.6	3.5	3.2	3.8	3.6	2.7	4.1	3.2
Organic and inorganic	9.3	6.3	4.3	3.8	4.5	3.4	4.3	3.4	6.4
Plastics	4.8	4.7	4.7	3.6	4.3	2.7	1.2	3.5	4.1
Others	3.6	4.3	2.7	3.3	4.1	3.7	3.1	2.7	3.5
Coal and petroleum products	1.8	3.3	2.6	2.1	2.4	1.1	1.0	1.0	1.9
Ceramics and clay products	2.3	3.0	1.8	2.4	2.2	1.6	1.4	1.6	2.1
Basic metals	5.2	2.8	2.7	2.3	2.1	3.2	1.3	1.5	3.5
Metals products	3.2	2.7	2.7	2.2	2.7	3.6	3.0	3.7	3.0
General machinery	28.0	27.4	24.7	24.4	22.4	22.8	24.8	22.7	25.8
Milling machinery	2.8	3.4	3.3	2.4	2.4	2.2	1.3	2.2	2.6
Specialized machinery	17.0	14.4	14.2	14.0	13.9	12.5	15.2	14.3	15.3
Other machinery	8.2	9.6	7.2	8.0	6.2	8.1	8.3	6.1	7.9
Electrical equipment	18.3	14.2	16.6	15.7	13.5	16.5	15.6	22.1	17.1
Power transmitter	2.9	1.4	1.3	1.1	2.2	1.9	1.4	1.4	2.1
Communications appliances	6.3	6.2	10.8	7.3	6.0	6.1	4.7	14.3	7.3
Eletronics equipment	1.9	4.5	3.3	6.1	4.3	8.1	8.1	5.2	4.0
Other equipment	7.1	2.1	1.3	1.3	1.0	0.4	1.4	1.3	3.7
Transporation equipment	5.4	5.3	4.8	5.5	5.9	4.8	5.3	4.4	5.3
Precision machinery	2.6	2.5	3.7	3.0	4.0	3.7	5.0	3.0	3.1
Miscellaneous	7.3	13.3	16.0	16.2	16.4	16.9	17.8	13.0	12.1
Total	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0

Source: MOF, *Monthly Report on Financial Statistics,* in EPA, Summary 1979 advanced foreign technologies came in the form of either imported machinery and equipment or through licensed Japanese manufacturers who produced with or without foreign equity participation (Hirono 1985); and (b) that these industries were the initial focus of the industrial policy after the war, thus synchronizing the technological development strategy with the general framework of industrial policy.

The process did not remain static. In fact, a new trend in technological innovation emerged in the 1970s (Hirono 1985). Although foreign advanced technology continued to flow in, greater emphasis was given to research and development (R&D) to develop indigenous technology. Also, pressures arose from the fact that local manufacturers were finding it hard to import advanced foreign technologies when they had no technologies to offer in return. Furthermore, there were clear indications that Japan had been fast closing the technological gap with the advanced countries of Europe and America. Table 16 shows that while the total number of licensed technologies increased from 564 in 1963 to 952 in 1968, imports of new technologies declined from 366 in 1963 to 282 in 1968. As a result, the ratio of new imported technologies to total licensed technologies drastically went down from 64.9 percent in 1963 to 29.6 percent in 1968. All this indicates that the number of attractive technologies that could be imported on profitable terms declined significantly during the period.

Because of the overwhelmingly positive spillover effects of R&D on the technological base, both Japanese industrialists and the government stepped up their R&D activities. Figure 7 indicates the rise in R&D expenditure. From a ratio to gross national product (GNP) of 1.3 percent in 1962, it increased to 1.7 percent in 1970, 2.0 percent in 1980, and 2.7 percent in 1989. Aside from government R&D expenditure, the government also actively promoted science and technology in general. Table 17 shows the rapid increase in the government budget for the promotion of science and technology. From 9 billion yen in 1963, the promotional budget increased to 37.4 billion yen in 1972 (about 3.3 percent of the total national budget). These funds were budgeted for national universities, research institutions, subsidies, among others (Tables 18a and 18b).

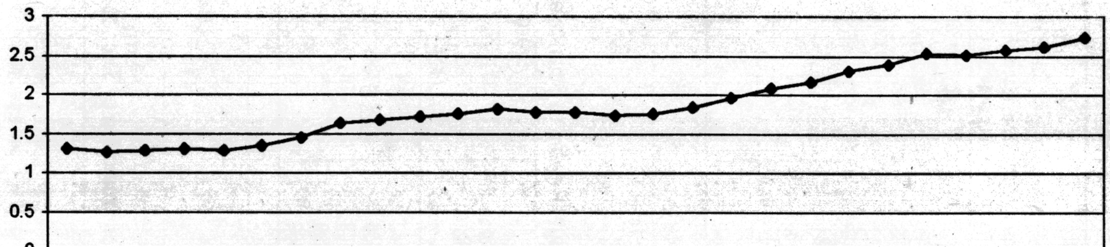
Another important component of the technological development strategy in Japan was that while the government promoted its development in line with the industrial policy, it placed the private sector in the forefront of R&D activities. As we shall observe later, the private sector accounted for the main part of R&D activities, having been motivated by various forms of government incentives and subsidies.

Table 16. Imports of New Technology

	1963			1966			1967			1968		
	Total number licensed (a)	New technology developed (b)	(b)/(a) %	Total no. of licensed (a)	New technology developed (b)	(b)/(a) %	Total no. of licensed (a)	New technology developed (b)	(b)/(a) %	Total no. of licensed (a)	New technology developed (b)	(b)/(a) %
Machinery	274	175	63.9%	182	77	42.3%	189	86	45.5%	313	97	31.0%
Electrical machinery	122	75	61.5%	83	30	36.1%	96	33	34.4%	192	26	13.5%
Metals and products	16	8	50.0%	43	23	53.5%	30	15	50.0%	56	13	23.2%
Chemistry	93	58	62.4%	140	55	39.3%	165	49	29.7%	229	91	39.7%
Atomic energy	2	2	100.0%	3	3	100.0%	3	0	0.0%	5	3	60.0%
Others	57	48	84.2%	74	41	55.4%	71	15	21.1%	157	52	33.1%
Total	**564**	**366**	**64.9%**	**525**	**229**	**43.6%**	**554**	**198**	**35.7%**	**952**	**282**	**29.6%**

Source: White Papers of Japan, 1971-72

Figure 7. R&D Expenditure/GNP (%)



	1962	63	64	65	66	67	68	70	71	72	73	74	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89
R&D expenditure/GNP	1.3	1.26	1.29	1.3	1.28	1.36	1.45	1.63	1.67	1.72	1.76	1.81	1.77	1.77	1.74	1.75	1.83	1.95	2.08	2.17	2.31	2.38	2.52	2.51	2.57	2.62	2.74

Sources: Various issues of White Papers of Japan, Muta (1993), Ministry of Labor and Science and Technology Agency

Table 17. Trends in Science and Technology-Related Budget (Y100 million)

	Total budget related to promotion of S&T	Budget for promotion of S&T	Other research related budget	Ratio to national budget (%)
1963	906	366	540	
1964	1089	424	665	
1965	1323	466	857	
1966	1430	532	898	
1967	1678	607	1071	3.4
1968	1919	734	1185	3.3
1969	2214	916	1298	3.3
1970	2635	1142	1493	3.3
1971	3054	1338	1716	3.2
1972	3740	1684	2056	3.3

Source: White Papers of Japan, 1973-74

Table 18a. Breakdown of Total Budget Related to Science and Technology (Y100 million)

	Total budget related to the promotion of S&T	Expenditure for national universities	Subsidies	Expenditures for national research and experiment institutions	Administrative expenses, etc.
1968	1,919	962	255	451	251
1969	2,214	1,056	347	500	311
1970	2,635	1,149	475	571	440
1971	3,054	1,280	595	665	514
1972	3,740	1,482	838	758	662

Source: White Papers of Japan, 1973-74

Table 18b. Breakdown of Budget for Promotion of Science and Technology (Y100 million)

	Budget for promotion of S&T technology	Expenditures related to nuclear power	Expenditures for national research and experimental institutions	Subsidies	Expenditures related to space development	Adminstrative expenses, etc
1968	734	208	306	160	41	19
1969	916	299	347	187	61	22
1970	1,142	390	394	212	119	27
1971	1,338	476	476	250	124	12
1972	1,684	562	521	361	206	34

Source: White Papers of Japan, 1973-74

Choice of Appropriate Technology

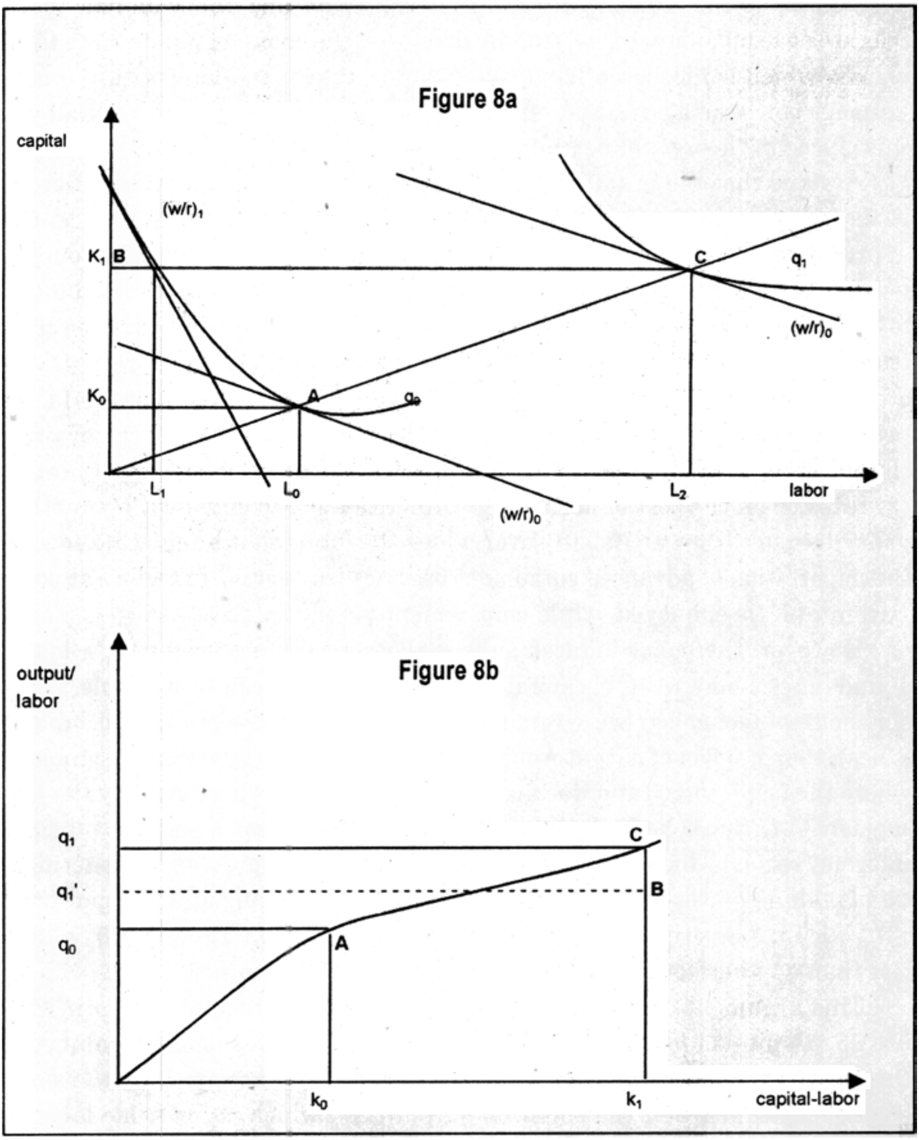
Central to the economic literature in the 1950s and 1960s on how to accelerate development was the lengthy debate on the choice of appropriate technology, which is discussed lengthily in the next section along with the government policy measures that effected this choice. At this point, we shall put this choice in theoretical perspective.

Assume that the initial factor price ratio is $(w/r)_0$ in Figure 8a, where w is the wage rate while r is the price of capital. Given this factor price, the appropriate choice of technology is given at point *A*. At this point an output level of q_0 is produced. In modernizing the sector, government exerted effort to substitute labor for advanced equipment and machinery, which is equivalent to shifting the point of operation to point *B*. This point represents another set of technology which is usually arrived at by distorting the factor price ratio to $(w/r)_1$. Normally, the policy measure to effect this factor price change is by artificially lowering r through government subsidies on interest rates or on the cost of borrowing. Often, this is accompanied by another policy measure that artificially overvalues the foreign exchange rate so that the importation of advanced equipment becomes less costly. Therefore at point *B*, capital K_1 is employed, while employment is reduced to L_1.

However, the policy-induced shift is theoretically inefficient. In a labor-abundant economy, at K_1 of capital, L_2 of labor may be readily available. If the old choice of technology were retained (represented by the ray in which point *A* lies), then q_1 level of output would be attainable. In the choice of technology where the factor price ratio was distorted, $(w/r)_1$, labor represented by the line segment L_1L_2 would be forced to work in the less productive and less efficient informal sector, which is outside the sector where the process of modernization is taking place. This informal sector will be producing at an output level of q_i, which is less than the difference between q_0 and q_1. Thus, $q_0 + q_i$ will be less than q_1. Therefore, the new choice of technology is inefficient.

This argument can also apply to the production function shown in Figure 8b. Capital of k_0 that produces an output of q_0 corresponds to point *A* in the previous chart. If capital is augmented to k_1, which represents the same level of capital earlier, the potential output is q_1, which is the same level as in the previous chart. However, with a distorted factor price, q_1 is not attained. It is q_1' that is reached, which is lower than q_1. The gap between $(q_1 - q_1')$ represents the loss in potential output due to technical inefficiency. The inefficiency can be due to a number of factors like the lack of mastery of the

Figure 8. Analysis of Appropriate Technology



adopted production engineering and method and the absence of competitive incentives due to price distortions created by government subsidies.

Thus, given this labor-abundant economy, the appropriate choice of technology should be small-scale and labor-intensive, which require a small amount of capital investment. This kind of technology would generate maximum employment effects. It is not developed in foreign countries, being a traditional domestic technology.

It is important to highlight the results of this theory in discussing the Japan experience because, given its factor endowments, which can be generally described as labor-abundant, and inadequate supply of raw materials, Japan had opted for something like point *B* for its choice of technology instead of point *A*. In particular, Japan did not substitute labor for capital but for resources (Choi 1983). Furthermore, it increased the efficiency of limited capital by using high and advanced technology in its pursuit of export-oriented industrialization. It strengthened the international competitiveness of few and key strategic industries by a bold introduction and application of up-to-date advanced technologies developed in foreign countries. The possible theoretical results of the shift, as discussed above, may potentially result in some inefficiency. But in the case of Japan, because of its well-planned and well-coordinated industrial policy, it successfully adapted advanced western technologies to its own particular economic conditions in its industrialization process. It also overcame the possible inefficiencies and therefore attained a rapid economic growth. Imported technologies were adapted to specific industrial, commercial, and market requirements in Japan. Product development, including design and packaging was made to fit local preferences, as were advertising, sales promotion, and customer services (Hirono 1985). The point to emphasize here is that the choice of appropriate technologies should fit well into the circumstances affecting the economy. The technological adaptation effort, therefore, must be within the overall framework of industrial policy.

Government Policies

In the early 1950s the government passed two important laws to re-invigorate the economy after the ruins of the war.[7] These were the Law for the Acceleration of Rationalization of Enterprises and the Special Taxation

[7] Discussion is largely based on Takafusa (1995)

Measures Law. The former, drawn up by MITI in 1952, designated the following industries to be the main focus: iron, steel, steel rolling, oil refining, metals, chemical fertilizer, soda, and dyes (Takafusa 1995). Policy measures targeted to these industries included subsidies to upgrade technology; loans of government-owned machinery and equipment; shortened depreciation period for experimental and research facilities; special depreciation provisions for the installation of modern plant and equipment, in particular, 50 percent depreciation of the purchase price in the first year; and reductions in excise taxes for modern plant and equipment. According to Takafusa (1995), the reduction in excise taxes for fixed assets and the depreciation of 50 percent proved to be effective in stimulating corporate investments.

Furthermore, the law also required both central and local governments to improve roads and port facilities, which where essential to further stimulating industry. Construction of infrastructure was basically funded from public resources to attract more industries to the rural regions.

The Special Taxation Measures Law, on the other hand, allowed the acceleration of depreciation. In particular, it allowed 40 to 50 percent of the value of a machine to be depreciated and counted as a loss in the first year or so after installation even though the machine was expected to last more than 10 years. Under this scheme, when companies made big investments, their losses got magnified, resulting in lower profits and therefore lower tax base.

Takafusa (1995) says the accelerated depreciation scheme was flawed from the perspective of "fairness," but adds that the law was designed in the first place to favor accumulation of capital. On hindsight, it may be safe to argue that the incentives provided by these laws played a major role in the postwar development of Japanese industry, as many companies embarked on ambitious programs of capital investment. Moreover, it was in the 1950s when Japan's policies took shape and proved to be effective.

The postwar period also witnessed the passage of two landmark pieces of legislation, based on MITI's belief that the machine and electronic industries were vital to industrialization. These were the Law for Special Provisional Measures to Promote the Machinery Industry and the Law for Special Provisional Measures to Promote Electronics Industry. These laws allowed MITI to draw up rationalization plans and to secure funds for their implementation from these industries. Furthermore, according to Takafusa (1995), these laws allowed the establishment of "cartels covering the items manufactured, their quantities, and technology."

Government continued to pursue policies for the promotion of technological innovations.[8] Hirono (1985) groups these policies into three main categories: (a) tax measures; (b) provisions of government subsidies to private industry, research organizations, and universities and other institutions of higher learning and specialized disciplines; and (c) provision and improvement of economic, social, and administrative infrastructure for promoting R&D activities and technological innovations in the private sector.

The tax measures included the accelerated depreciation of allowances for plant, machinery, and equipment used in R&D activities in the strategic sectors identified by the MITI. There were also reductions in real estate or property taxes and business taxes for R&D installations and programs in "technopolis" (locations of technology industries) across the country. In particular, partial deductions were allowed from corporate income tax in cases where (a) R&D expenditures went beyond the maximum in the past tax years; (b) income was derived from technology export; and (c) pecuniary contributions were made to non-profit research organizations.

Other local tax measures were exemptions of property tax, utilities tax, and property acquisition tax for R&D installations and assets acquired by non-profit educational institutions; and reduction in property tax for R&D plant and equipment owned and managed by mining and industrial technology research cooperatives.

High tariffs, including quantitative import restrictions and other non-tariff barriers, were also utilized to shield the protected strategic sectors from foreign competition and to widen local production and the industrial base of Japan. The strategic sectors importing advanced technologies received attractive export incentives so they could expand both their output and export, thus exploiting the economies of scale in production.

Table 19 shows a detailed set of fiscal incentives for technology-related activities in Japan. Incidentally, some econometric studies confirmed that in the 1950s, the fiscal incentives were fairly effective in raising the level of private investment (Nagaoka 1989). In particular, the accelerated depreciation scheme helped companies not only by increasing their rate of return from investment but also by reducing credit risks for banks. Studies also show that targeted measures, such as tax exemptions for commercializing new products,

[8] Discussion here is largely based on Hirono (1985), which in turn was largely based on the *Science and Technology Agency White Paper*, 1982.

Table 19. Fiscal Incentives for Introduction of New Technology in Japan

Schemes	Fiscal Granted
1. Abatement of Tax and Tariff	
a. Income tax exemption for commercialization of new important products (1923-1966)	Tax on the income generated from the production of new products designed by the government was fully waived for about four years.[A]
b. Reduction of the withholding tax on external payment associated with important technical licensing (1953-1967)	The withholding tax was reduced by 10 percent (later 15 percent)
c. Import duty exemption for importing important machinery (1951-1965)	Imported duties on machinery designated by the government were exempted. The eligible machinery were (1) new or highly efficient industrial machinery, (2) machinery difficult to be manufactured in Japan, and (3) machinery necessary for industrial development.[B]
d. Income tax credit for the increase in expenditure for research and development (1966-present).	If a firm's annual R&D expenditure exceeded the peak amount in the previous years, 25 percent of the excess was allowed as a tax credit.[C] The credit was raised to 50 percentfor the portion of the excess alone of 15 percent of the amount spent in the previous peak year. The credit has been limited to 10 percent of the amount spent corporation income tax.
2. Accelerated Depreciation[D]	
a. Important machinery (1951-1961)	50 percent additional depreciation for the first three years, relative to the ordinary depreciation schedule.
b. Machinery for rationalization (1952-)	50 percent depreciation in the first year.
c. Machinery for testing and research (1958-1965)	50 percent, 20 percent, and 20 percent depreciation for the first, second, and third year, respectively.
d. Machinery for commercializing new technology (1958-1965)	50 percent depreciation for the first year.
e. Equipment produced for the first time in Japan (1964-)	One-third depreciation for the first year.
f. Machinery for the modernization of small and medium size industry (1963-)	One-third depreciation for the first three years

Source: Nagaoka (1989)

[A] Before the revision of 1957, this scheme used to apply not only to the commercialization of new products but also to the production of such products as minerals and coals.

[B] The revision took place in 1960. The scheme was transformed to serving the prevention of industrial pollution, etc., from serving industrial development

[C] Currently 20 percent of the excess can be counted as a tax credit.

[D] Right-hand column describes incentives applicable from 1958-1960. Major curtailment took place in 1961 with some incentives integrated in the statutory schedule of depreciation.

were ineffective in encouraging new industries to grow, especially during their infancy or initial stage. These industries involve synthetic fibers, synthetic rubber, fertilizer, petrochemicals, and antibiotics.

Apart from tax reductions and exemptions, there were also provisions for low-interest loans by government financial institutions. For example, the Japan Development Bank provided such low-interest loans for R&D activities developing indigenous technology, innovating large-scale computer technology, and producing high technology in electronics and machinery industries.

Another example was the SME finance corporations' provision of loans with low interest rates to smaller enterprises that conducted R&D activities related to new developments in technologies and in electronics and machinery. The center for development of R&D enterprises provided smaller industries with guarantees for their R&D loans from commercial banks. Furthermore, the small and medium enterprises credit insurance extended the insurance coverage for R&D activities and for commercializing new technologies.

Another form of government support was the provision of subsidies to private industry and research organizations and universities, including institutions of higher learning and specialized disciplines. Covered in this category were R&D activities in priority areas such as nuclear and other sources of energy, space, marine resources development, biotechnology, among others. The Ministry of Education provided subsidies to R&D programs in science and technology in the state universities, research institutions, as well as private universities. For its part, the New Technology Development Corporation granted subsidies to private industry to develop new technologies and to encourage government research laboratories and universities to transfer technologies to the private sector.

MITI contracted out to the private industry many of the required R&D activities for developing new large-scale industrial technologies, energy-saving technologies, and new alternative sources of energy, as well as for innovating medical, health and welfare equipment manufacturing technologies, and basic technologies for future industries.

The amount of subsidies granted to R&D-related activities was huge. For example, in 1980 the subsidy from the Science and Technology Agency amounted to 307.9 billion yen, from the Ministry of Education 166.1 billion yen, and from the MITI 119.2 billion yen. Overall, these subsidies comprised 91.6 percent of all government subsidies for R&D activities in the private sector in 1980, including universities and research organizations. Table 20 lists down some specific incentives granted by the government for R&D-related activities in Japan.

Here is one very important lesson that can be gleaned from the Japan experience in granting incentives: Although these incentives were directed to particular groups of industries, a competitive scheme in granting the incentives was pursued based on certain criteria set by the government. This process effectively eliminated the possibilities of rent-seeking behavior.

The last category of government support involved the provision and improvement of the economic, social, and administrative infrastructure for promoting R&D activity and technological innovations in the private sector. A major part of this effort was the establishment of a national network on scientific and technological information through improved cooperation and coordination among public and private agencies collecting, collating, analyzing, evaluating, and publishing science and technology information material in and outside of Japan. The Tsukuba Research and Development Park, which was established in 1971, accelerated the research and education on science and technology by bringing together government research laboratories, educational institutions, and selected private research organizations and universities.

Still another important component of this government support was the streamlining of technical evaluation procedures and systems, including industrial standards. As such government and semi-government research laboratories and testing stations were significantly upgraded.

Research and Development

Basic structure. As earlier discussed, R&D efforts in Japan increased substantially. This was indicated by the rise in the ratio of R&D expenditure to GNP mainly due to the development of indigenous technologies when Japan was already approaching the technological limits of advanced countries in Europe and America. Initially, the strategy of Japan was to import advanced technology from these countries. However, the development in Japan was so rapid that it was able to close the technological gap in a relatively short period of time.

Although the government actively promoted technological development, as evidenced by the various forms of support and subsidies it extended to

Table 20. Major Incentive Schemes for R&D in Japan: Conditional Loan, Financial Assistance and Government-Sponsored R&D in 1960s and 1970s

Incentive Scheme	Type	Description
1. Conditional loan		Fiscal support granted (around 50% of R&D cost) must be repaid, depending on the profit generated by the technology or on the success of the development project. Patents or any other research results belong to enterprises.
	a. Important technology in industry and mining (1950-).	Eligible R&D projects are chosen out of applications from industry on the competitive basis, according to criteria set by the government.
	b. Technology improvement for SMEs (1967-).	The same scheme, but eligibility restricted to small and medium enterprises.
	c. Computer development (1972-).	Targeted support for the development of computer and aircraft industry.
	d. Aircraft development (1968-).	
2. Financial incentive		Below market interest rate loan to cover around 50 percent of the project cost (financing period up to 15 years).
	a. Loan by the Japan Development Bank (1951-).	Soft loan is provided for the commercialization of new technology, development of heavy machinery, and commercialization of new machinery.
	b. Loan by Small and Medium Business Finance Corporation (1970-).	Soft loan is provided for the commercialization of new tehcnology and for the prototype development of new machinery.
3. Government-sponsored R&D		The patents originated from research usually belong to the government and are available to any enterprises (i.e., nonexclusively), including a participating enterprise.
	a. Large-scale project (1966-)	The government identifies R&D projects, which cannot be undertaken by enterprises in spite of high social returns, and sponsors their implementation (16 completed projects and 7 ongoing projects in 1987).

Source: Nagaoka, 1989

the private sector, it was the private sector that always dominated all R&D activities in Japan. Table 21 and Figure 9 indicate that almost 70 percent of the total R&D expenditures came from various private companies. In the 1960s, research institutes accounted for about 17 percent of such expenditures, which then rose to more than 20 percent in the 1970s. The share of universities went down from more than 20 percent in the 1960s to less than 10 percent in 1980. All this would indicate that although the government actively pursued technological development in Japan, it took the back seat as it set up the necessary infrastructure for technological development and granted incentives to the private sector.

The United Nations Educational, Scientific, and Cultural Organization (UNESCO) defines three major categories of R&D activities, namely, basic research, applied research, and experimental development. Basic research involves any experimental or theoretical work undertaken primarily to acquire new knowledge of the underlying foundations of certain phenomena and observable facts, without any specific application or use in view. Applied research encompasses any original investigation undertaken to acquire new knowledge. It is, however, directed primarily to a specific practical aim or objective. Experimental development comprises any systematic work, drawing on existing knowledge gained from research and/or practical experience that is directed to producing new materials, products, and devices; to installing new processes, systems and services; and to improving substantially those already produced or installed.

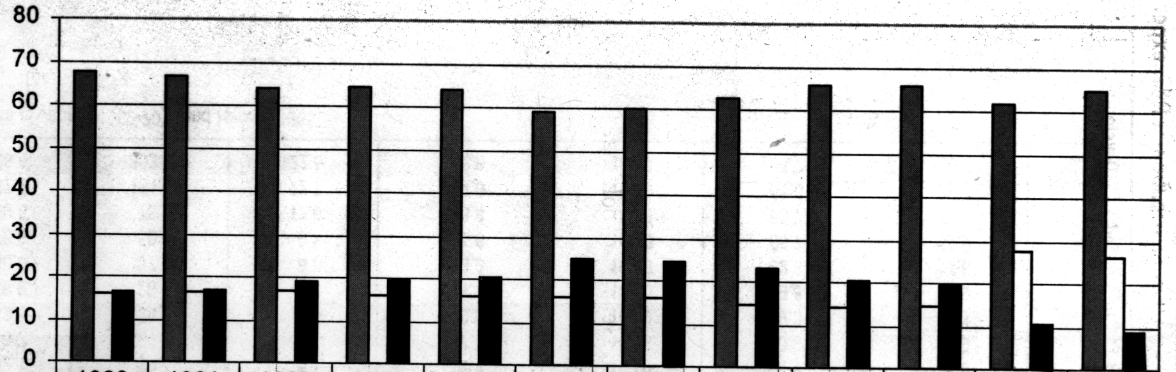
Table 22 shows the breakdown of R&D activities in Japan in terms of the three categories and type of organization. On the whole, the emphasis of R&D was on the third category due to the effort of the private sector, which dominated the R&D field, to focus on development research. Its share increased from 49.1 percent in 1970 to 58.4 percent in 1978. Basic or fundamental research as well as applied research went down over the same period. Development research of the private sector increased from 63.6 percent in 1970 to 77.1 percent in 1978. Research institutes, which captured about 20 percent of R&D activities, focused largely on applied and development research, as indicated by the share of about 40 percent in each category. Universities were originally into fundamental research, but moved into more applied research, as indicated by their shares. In 1970 the share of fundamental or basic research in the universities was 80 percent. In 1978, it went down to 57.3 percent. On the other hand, the share of applied research increased from 20 percent to 37.3 percent over the same period.

Table 21. R&D Expenditures

	Expenditure (\billion)				Percentage Share			
	Total	Companies	Research institutes	Universities	Total	Companies	Research institutes	Universities
1960	18.4	12.4	2.9	3.1	100.0	67.4	16.0	16.6
1961	24.5	16.4	4.0	4.1	100.0	66.8	16.3	16.9
1962	28.1	17.9	4.8	5.4	100.0	63.8	16.9	19.3
1963	32.1	20.7	5.1	6.3	100.0	64.6	15.9	19.5
1964	38.2	24.4	6.1	7.7	100.0	63.9	15.9	20.2
1965	42.6	25.2	6.8	10.5	100.0	59.3	16.1	24.7
1966	48.9	29.2	7.8	11.9	100.0	59.8	15.9	24.3
1967	60.6	37.9	8.8	13.9	100.0	62.5	14.6	22.9
1968	76.8	50.4	10.8	15.6	100.0	65.7	14.0	20.3
1970	119.5	78.5	17.6	23.4	100.0	65.7	14.7	19.6
1975	262.2	161.6	72.7	27.9	100.0	61.6	27.7	10.6
1980	468.4	303.2	122.5	42.6	100.0	64.7	26.2	9.1

Source: White Papers of Japan (1969-70), and Hirono (1985)

Figure 9. Components of R&D Expenditures (%)



	1960	1961	1962	1963	1964	1965	1966	1967	1968	1970	1975	1980
Companies	67.436	66.818	63.808	64.552	63.873	59.262	59.791	62.506	65.685	65.675	61.642	64.737
Res. Institutes	15.952	16.277	16.941	15.935	15.879	16.069	15.885	14.59	14.02	14.708	27.723	26.161
Universities	16.612	16.905	19.251	19.513	20.249	24.669	24.323	22.904	20.295	19.618	10.635	9.1021

Table 22. Type of Research by Organization (percent distribution of R&D expenditures)

	Fundamental	Applied	Development	Total
Overall				
1970	23.3	27.6	49.1	100.0
1978	16.5	25.1	58.4	100.0
Companies				
1970	9.2	27.2	63.6	100.0
1978	4.7	18.2	77.1	100.0
Research institutes				
1970	17.8	42.1	40.1	100.0
1978	17.6	38.7	43.7	100.0
Universities				
1970	80.0	20.0	0.0	100.0
1978	57.3	37.3	5.4	100.0

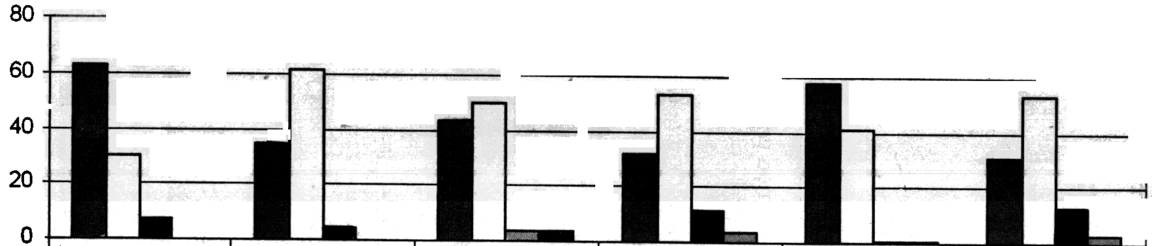
Source: White Papers of Japan, 1971-72 and 1979-80

Of the OECD countries, Japan and Germany took a generally similar path in R&D, in which the industry took a dominant share, in contrast to countries like the United States, France, Canada and the United Kingdom, where the governments took the commanding share in R&D expenditure (Figure 10).

Objectives of technology. The White Papers of Japan on Science and Technology regularly publish survey results on the objectives of the private sector in its technological efforts. Table 23 shows the major shifts in its emphasis over time. In the 1950s, the dominant concerns were better quality and performance (40 percent) and mass production (23 percent). Through time, however, as some of these objectives were realized, emphasis shifted to other concerns like resource conservation (18 percent) and energy conservation (18 percent). Despite the major shift, however, the objectives of better quality and performance remained paramount.

Public-private sector link. As discussed earlier, although the private sector played the leading role in technological development in Japan, the support extended by the public was significant. In 1961 the law governing research associations was implemented. It gave a legal status to cooperative research associations. Thus, to foster further the link between the private and the public sectors under this law, R&D cooperatives were installed in major private enterprises interested in technological innovations under the guidance and financial assistance of the MITI. Such cooperatives were crucial to the development of large-scale computers and integrated circuits. They

Figure 10. Percentage Share of R&D Expenditure by Organization in Major Countries



	Japan	USA	United Kingdom	France	West Germany	Canada
Series1	62.9	34.4	43	31.5	57.5	
Series2	30.2	61	49.6		41.3	
Series3	6.9	4.6			0.7	
Series4					0.5	

Source: White Papers of Japan, 1970-71

Series 1	Industry
Series 2	Government
Series 3	Non-Profit Organizations and Universities
Series 4	Overseas

Table 23. Trends in Objectives of Technology (by private sector)

	Better quality and performance	Convenience and comfort	Mass production	Environmental preservation	Safety	Labor saving	Resource conservation	Energy conservation	Total
1950	40	14	23	2	5	9	5	2	100
1960	38	15	19	4	6	10	5	3	100
1970	31	14	11	9	8	11	8	8	100
1980	23	11	8	7	7	8	18	18	100

Source: White Papers of Japan, 1979-80

also proved vital to the apparel and non-ferrous metal manufacturing industries. The policy proved to be very effective in research involving high-risk, high-cost and long-gestation R&D programs designed to develop indigenous technology. From 1961 to 1983, 71 research associations were established. The government led the establishment of these cooperatives, which were used as implementing organizations for government-assisted R&D projects.

A number of concerns, however, were raised against the establishment of these cooperatives. For example, there were fears that the cooperatives might not generate positive results because the participating companies were in stiff competition against each other both in the factor and production markets. As such these companies would not assign their best scientists and engineers to such cooperatives (Hirono 1985). Another concern was that such cooperatives might prevent free competition among the participating firms, resulting in inefficiency. Furthermore, there were criticisms from the United States that such cooperatives might result in unfair competition between Japanese and American companies, thinking that through the cooperatives, Japanese companies might be pooling their resources together and that the government might be subsidizing the participating enterprises to make them more competitive in the international market.

Another means whereby the link between the private and the public sectors was reinforced was through the establishment of 19 technopolis of the MITI, where government financial resources were utilized to install the most up-to-date economic and social infrastructure and facilities conducive to the activities of technology-intensive industries. The facilities included specialized R&D laboratories. The local governments were also fairly active in supporting the private sector's effort toward technological innovations in these technopolis.

Another very important feature of R&D in Japan in the early years was the existence of trading companies that facilitated the importation of technologies, both general and specialized, most suited to local manufacturers. Such trading companies served as the identifiers of technology needs within Japan and of the availability of such technologies abroad. These companies were instrumental not only in supplying information to the technology buyers in Japan, but also in investing their own financial resources in setting up their manufacturing subsidiaries either unilaterally or in joint ventures with foreign suppliers of imported technologies or the local buyers of technologies (Hirono 1985). But as the local buyers of technologies gained valuable experience, they imported their own technology requirements. Local manufacturers also sent local engineers and managers for training abroad. This development was facilitated by the Japan External Trade Organization, a subsidiary of MITI, which obtained the necessary information on the nature, costs, and benefits of alternative technologies available abroad.

National research laboratories played an important complementary role for private R&D. These laboratories served five areas: (a) basic research not undertaken by universities; (b) applied research involving large-scale research equipment; (c) technology transfer; (d) research that private industry could not adequately undertake (e.g., pollution issues); and (e) research for the establishment of standards, testing methods, and norms. Furthermore, these national research laboratories provided basic technological information in the planning stages of private R&D (Nagaoka 1989). Together with MITI these laboratories played a major role in cooperative R&D. In addition, they were the major agents of assessing private R&D projects assisted by the government. Also, by accepting researchers from the private enterprises as trainees, these laboratories were able to transfer R&D skills to the private sector.

Patent system. Japan has a long history of patent protection (Nagoaka 1989). The first patent regulation was established in 1885. In 1899 it acceded to the Paris Convention and accepted applications by foreigners. Active patenting activities have remained active since then. One feature of the system was the protection of a utility model.[9] More than 40 percent of the world patent applications have been filled by the Japanese in recent years.

[9] Patent protection for utility model was implemented by virtue of a 1905 legislation that followed the German system as a model.

Apparently, R&D activities have been encouraged greatly by the very active patent system in Japan. Apart from the system's positive impact, particularly with respect to the appropriateness of R&D benefits, it provided a vehicle for evaluating and recognizing the technological effort of workers by the patent experts. In particular, many companies in Japan offered a special incentive to encourage employees to create innovations and suggest improvements. This widened the participation in inventing activities in Japan.

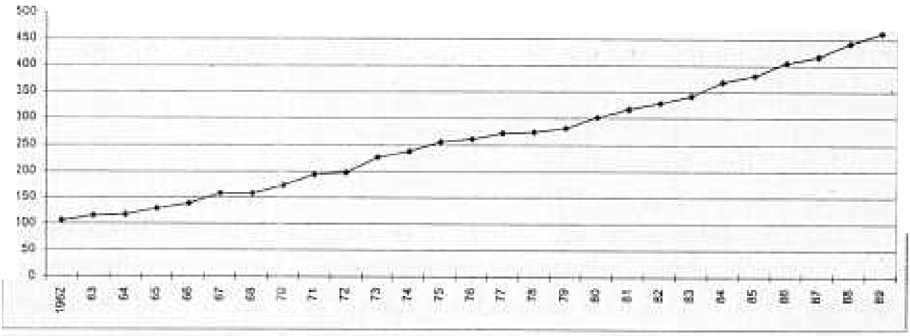
Manpower Development

Structure of workforce. One of the major driving forces of technological development and rapid economic growth in Japan was the absorptive capability of its manpower. Imported technologies were adapted, assimilated, and diffused because of its well-trained labor force. Figure 11 shows the continuous rise in the pool of researchers; from 106 researchers per 1000 persons in 1962, the number grew to 172 in 1970, 303 in 1980, and 462 in 1989. Similar to R&D expenditure discussed above, the private sector employed a sizeable part (more than 50 percent) of this pool of researchers (Table 24). Research institutions employed fewer researchers compared to the universities as a whole.

As expected, in terms of research specialization, the researchers specialized in areas where demand existed. Table 25 indicates that in the second half of the 1960s, more than 20 percent of the researchers specialized in chemistry and related fields, 14 percent in machinery, and about 12 percent in electrical and related fields. Of those employed in the private sector, more than 30 percent had specialization in chemistry, 20 percent in machinery, and 18 percent in electrical and related fields. Note that these were the same industries on which the early industrialization process after the war focused. In research institutes researchers specialized in agriculture (about 27 percent) and chemistry (16 percent), while researchers in universities were in medicine (about 40 percent) and chemistry (11 percent).

Formal educational system. The early educational system in Japan can be traced back to the Meiji Restoration that began in 1868, when a group of reform-minded leaders created an educational system that integrated various aspects of French, German, and other Western models with indigenous social and cultural elements. However, after World War II when Japan was occupied by the Americans, the system was modified through major reforms.

Figure 11. Researchers per 1000 Persons



Source: White Papers of Japan, various issues, Muta (1993), Ministry of Labor and Science and Technology

Table 24. Number of Researchers Employed

	Researchers Per 1000 Persons				Percentage Distribution (%)			
	Total	Companies	Research institutes	Universities	Total	Companies	Research institutes	Universities
1960	86.8	43.6	14.9	28.3	100.0	50.2	17.2	32.6
1961	90.9	46.1	16.5	28.3	100.0	50.7	18.2	31.1
1962	105.9	54.1	18.3	33.5	100.0	51.1	17.3	31.6
1963	114.8	60.0	18.4	36.4	100.0	52.3	16.0	31.7
1964	117.6	59.0	19.5	39.1	100.0	50.2	16.6	33.2
1965	128.9	65.4	19.9	43.6	100.0	50.7	15.4	33.8
1966	138.7	69.2	21.0	48.5	100.0	49.9	15.1	35.0
1967	157.7	81.7	21.7	54.3	100.0	51.8	13.8	34.4
1968	157.1	82.5	22.2	52.4	100.0	52.5	14.1	33.4
1970	172.0	91.5			100.0	53.2		
1975	255.2	143.4			100.0	56.2		
1980	302.6	170.3			100.0	56.3		

Source: White Papers of Japan, various issues, and Hirono, 1980

Table 25. Specialization of Researchers (percentage distribution, %)

	Overall					Research Institute				
	1965	1966	1967	1968	1969	1965	1966	1967	1968	1969
Grand total	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
Mathematics, physics	7.5	6.8	6.9	7.0	7.7	6.5	6.1	6.2	6.1	6.2
Chemistry	23.1	22.1	22.9	22.7	21.3	15.9	15.6	15.6	15.6	14.7
Biology	1.7	1.5	1.5	1.4	2.0	2.8	2.8	2.6	2.4	1.9
Physical geography	0.7	0.7	0.7	0.7	0.9	1.5	1.4	1.4	1.5	1.7
Civil engineering, construction	2.9	2.8	2.9	2.9	3.1	2.9	2.9	2.6	2.4	2.6
Machinery, ship, aircraft	13.6	14.3	13.2	13.8	15.1	7.8	8.0	7.9	7.3	7.4
Electricity, communications	12.0	12.2	12.8	12.8	13.4	5.2	5.2	5.3	5.3	5.7
Mining, metallurgy	3.5	3.4	3.2	3.1	3.1	2.2	2.0	2.2	2.2	2.1
Textile	2.4	2.7	2.2	2.6	2.3	4.7	4.2	4.2	4.0	3.8
Agriculture, forestry	7.0	6.5	6.7	6.0	7.4	26.5	27.3	26.6	27.2	30.1
Fisheries	1.6	1.5	1.5	1.5	1.4	6.2	6.5	6.4	6.6	6.6
Animal husbandry, vet. sci.	2.2	2.0	2.0	2.1	2.0	7.6	7.3	7.7	7.6	7.6
Medicine, dentistry	13.8	15.1	15.1	15.1	14.2	3.0	2.7	2.7	2.9	2.8
Pharmaceutics	3.4	3.3	3.4	3.1	3.3	2.8	3.0	2.9	2.9	2.9
Others, incl. humanities and social sciences	4.7	5.1	5.1	5.2	2.8	4.3	4.9	5.5	5.9	3.9
	Company					**University**				
	1965	1966	1967	1968	1969	1965	1966	1967	1968	1969
Grand total	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
Mathematics, physics	6.3	5.6	5.6	5.9	5.6	9.7	9.0	9.2	8.9	11.3
Chemistry	33.3	32.0	33.6	32.7	30.1	11.3	10.3	10.7	10.5	11.0
Biology	1.0	0.9	0.8	0.9	1.1	2.2	1.9	2.0	1.9	3.3
Physical geography	0.2	0.2	0.3	0.3	0.2	1.1	1.0	1.1	1.1	1.6
Civil engineering, construction	2.1	1.9	2.0	2.1	2.4	4.0	3.9	4.3	4.3	4.2
Machinery, ship, aircraft	20.4	21.7	19.4	20.5	22.1	6.3	6.2	6.6	6.4	7.9
Electricity, communications	18.2	18.4	19.7	19.3	20.4	6.1	6.0	6.0	6.1	6.0
Mining, metallurgy	4.8	4.7	4.3	4.1	4.3	2.3	2.0	2.1	1.9	1.8
Textile	2.8	3.6	2.7	3.6	3.1	0.6	0.5	0.5	0.5	0.6
Agriculture, forestry	1.9	1.6	2.4	1.7	2.7	5.0	4.3	4.2	4.1	5.6
Fisheries	0.4	0.4	0.5	0.5	0.5	1.0	0.9	0.9	0.9	0.9
Animal husbandry, vet. sci.	0.8	0.7	0.6	1.0	1.0	1.7	1.6	1.4	1.4	1.3
Medicine, dentistry	0.2	0.2	0.2	0.2	0.2	39.6	43.0	41.7	42.4	38.7
Pharmaceutics	4.0	3.9	4.0	3.3	3.6	2.7	2.6	2.6	2.9	3.0
Others, incl. humanities and social sciences	3.6	4.1	3.9	3.9	2.5	6.4	6.6	6.7	6.9	2.8

Source: White Papers of Japan, various issues

The reforms were based on a mission report containing the blueprint for the postwar Japanese educational system submitted by a group of American educators and other U.S. experts. The basic philosophy of the reform was the democratization of education. The reform was meant to dismantle the centralized, multitrack educational system in Japan over the last three-quarters of the century into an American-style decentralized, egalitarian, single-track system. Japan had adopted a 6-3-3-4 single-track school system throughout the country. Six years of elementary education and three years of lower secondary education became compulsory.

The other major reforms in the educational system included: (1) the introduction of public elections for the boards of education; (2) the liberalized publication of textbooks; (3) the flexibility of planning for the school curriculum; (4) the consolidation of highly variegated secondary schools into middle and high schools; and (5) the consolidation of various institutions for higher education into two-year junior colleges and four-year universities.

When the American occupation ended in 1952, certain sectors sought to revive the old system. Indeed, several changes were re-introduced into the system, but still the egalitarian, open structure of the school system based of the American system remained.

During Japan's rapid growth in the 1950s, enrollment in secondary schools surged. The ratio of high school students increased from 52 percent in 1955 to 58 percent in 1960, to 71 percent in 1965, to 82 percent in 1970, and more than 90 percent in 1975. In 1991 enrollment in elementary and secondary schools reached 100 percent (Table 26). This high rate was mainly due to the compulsory educational system requiring six years of elementary and three years of lower secondary education.

Higher education also became popular, as evidenced by the sharp rise in enrollment in two- and four-year college courses. The ratio of 18-year-olds that proceeded to higher education increased from 10 percent in 1955 to 17 percent in 1965, to 24 percent in 1970, and to 38 percent in 1975. These results contrasted sharply with prewar levels. For example, in 1935 only 40 percent of all students who completed elementary schooling continued to secondary school, and only a tiny 3 percent went on to higher education.

Japan's educational system did not only provide an equal education opportunity, it also ensured the same quality of education in all schools, thereby reducing regional disparities. The generally similar quality of education across regions was ensured by the setting of clear standards for school facilities, and the existence of well-qualified and better-paid teachers, among others.

Table 26. Number of Schools, Teachers and Enrollment (as of May 1, 1991)

	Institutions	Teachers*	Enrollment	Enrollment rate
Kindergarten	15,041	101,493	1,977,611	64.1**
Elementary schools	24,798	444,903	9,157,429	100.0***
Lower secondary schools	11,290	286,965	5,188,314	100.0***
Upper secondary schools	5,503	286,092	91,534	95.4****
Special schools for handicapped	960	47,393	33,623	
Technical colleges (1-3 grade)	63	4,061	33,623	38.2*****
Technical colleges (4-5 grade)	-	-	20,075 (a)	55.5*****
Junior colleges	592	20,933	504,087 (b)	
Universities	514	126,445	2,205,516 (c)	
Special training schools (college level)	3,370	33,512	658,150 (d)	
Special training schools (others)	-	-	176,563	
Miscellaneous schools	3,309	18,745	406,599	

Source: Muta, 1993. Original source: Ministry of Education, Science and Culture, 1992a
* Full-time
** Kindergarten completed/first-grade enrollment. Nursery school completed is not taken into consideration.
*** Enrollment/school age population
**** Upper secondary school entrants/lower secondary school graduates
***** (a+b+c)/Lower secondary gradutes during the previous three years
****** (a+b+c+d)/Lower secondary graduates during the previous three years

Government support to the educational system was substantial. Both the national and the local governments were active in shaping up the system. In the period 1960 to 1965, the cumulative public education expenditure amounted to 5.9 trillion yen. Between 1971 and 1975, it increased to 27.7 trillion yen. From 1981 to 1985, it increased further to 78.6 trillion yen. The share of financial support from the national government was slightly lower than that of the local government—about 45 percent and 55 percent, respectively (Table 27). These resources went to elementary and lower secondary schools, which were compulsory in Japan (Table 28). There were also substantial shares from upper secondary schools and universities and colleges.

Private educational institutions played an important role in the overall system as well. In higher education, the majority of students attended private schools. Also, most of the special training schools and miscellaneous schools were private schools. Table 29 shows the number of private school students and teachers, and their proportion to the overall system.

Assistance to the private educational institutions from the government was also significant. In 1991, for example, the national government budgeted 364 billion yen in subsidies for the private schools. Of this amount, 70 per-

Table 27. Public Education Expenditure by Government

			Provided by National Government (%)				Provided by Local Government (%		
	Total, period sum (Ybillion)	Per-centage (period averages)	Sub-total	National educa-tional activities	Subsidies local to govern-ment	Part of the local allocation tax grant	Sub-total	Prefec-tures	Munici-palities
1960-65	5,919	100.0	49.1	13.2	21.5	14.4	50.9	30.5	20.4
1966-70	10,645	100.0	48.8	14.7	20.2	13.9	51.2	30.4	20.8
1971-75	27,711	100.0	46.0	12.2	19.7	14.1	54.0	29.9	24.1
1976-80	57,972	100.0	47.5	13.3	20.5	13.7	52.5	28.6	23.9
1981-85	78,633	100.0	45.0	13.7	18.7	12.5	55.0	29.9	25.2
1986-89	71,189	100.0	42.5	13.9	16.4	12.2	57.5	32.2	25.3

Source: Muta, 1993. Original source: Ministry of Education, Science and Culture

cent was spent for private universities and colleges, and 22 percent for upper secondary schools. Apart from these subsidies, the government also granted resources for educational and research equipment and facilities, which have been increasing in recent years.

Other trainings. Institutions for human resource development (HRD) and other trainings also existed. Both the national and local governments set up vocational institutions and centers, vocational training colleges, and skills development centers. In these institutions, trainings were also provided for the unemployed, those who wanted to look for jobs elsewhere, those who wanted to change jobs or look for another job after the mandatory retirement, and for the handicapped.

A major feature of the vocational training system in Japan is the active participation of the private enterprises (Nagaoka 1989). In fact, vocational training is mainly supported by the private sector, unlike countries in Europe where vocational institutions are public entities. In Japan, training is mostly on-the-job. However, these enterprises also provide seminars or formal training courses for employees. Many large companies finance graduate education abroad or in Japan. Company incentives are also provided for those who obtain certificates of skills training. Investment in HRD in Japan by the private sector is supported by the unique lifetime employment system widely adopted after the war. With this system, the private sector is encouraged to appropriate investments in training and education, since the employees are expected to work for them for many years. Thus, HRD practice at the company level played a major role in shaping up the pool of manpower in Japan.

Table 28. Public Expenditure on Education by Level of Education

	Total, period sum (Ybillion)	Percentage (period averages)	Kindergarten	Elementary	Lower secondary	Special education	Upper secondary	University and college	Special training college	Miscellaneous education	Social education (%)	Educational administration (%)
1960-65	5,919	100.0	0.6	36.3	24.1	1.0	16.1	12.6	-	0.0	2.7	6.5
1966-70	10,645	100.0	0.8	36.8	20.5	1.4	16.0	14.0	-	0.0	3.7	6.7
1971-75	27,711	100.0	1.3	37.9	19.9	1.8	15.6	11.0	-	0.0	4.9	7.5
1976-80	57,972	100.0	1.3	37.1	19.0	2.3	14.9	10.6	0.0	0.0	5.8	9.0
1981-85	78,633	100.0	1.2	33.5	19.4	2.5	15.2	11.0	0.0	0.0	7.2	9.9
1986-89	71,189	100.0	1.1	31.3	18.9	2.7	15.4	11.7	0.1	0.0	8.3	10.2

Source: Muta, 1993.
Original source: Ministry of Education, Science and Culture

Table 29: Number of Private Schools, Students and Teachers (as of May 1, 1991)

	Number of schools	Ratio of private sector (%)	Number of students	Ratio of private sector (%)	Number of teachers	Ratio of private sector (%)
Four-year university and college	378	73.5	1,610,135	73.0	65,310	51.7
Junior college	497	84.0	463,418	91.9	17,590	84.0
College of technology	4	6.3	3,072	5.7	174	4.3
Upper secondary schools	1,316	23.9	1,575,432	28.9	65,415	22.9
Lower secondary schools	617	5.5	210,921	4.1	9,874	3.4
Elementary schools	168	0.7	65,041	0.7	2,934	0.7
Schools for the handicapped	17	1.8	891	1.0	262	0.5
Kindergarten	8,769	58.3	1,560,274	78.9	76,153	75.0
Subtotal	11,766	20.0	5,489,184	22.3	237,712	18.0
Special training schools	3,022	89.7	788,661	94.5	30,744	91.7
Miscellaneous schools	3,221	97.3	399,805	98.3	18,303	97.6

Source: Muta, 1993.
Original source: Ministry of Education, Science and Culture, 1992

Administrative Structure

Figure 12 shows the administrative structure of science and technology in Japan. Science and Technology Agency (STA) is the country's highest administrative agency on science and technology. The policymaking function, however, was entrusted to the Council for Science and Technology (CST). While the Japanese Science Council, with a membership of 210 experts in 1979, deliberated on major theoretical issues and advises the government on science and technology matters, the CST was entrusted with the formulation of more concrete policies (Choi 1983). Other related agencies include the Atomic Energy Commission, the Space Activities Commission, and the Council for Ocean Development, which operates under the jurisdiction of the Office of the Prime Minister.

One feature of Japan's science and technology policy formulation is that the CST or the STA sets only policy directions, leaving the implementation to the relevant ministries and agencies. Another interesting feature is the leading role of businesses in industrial technology development. The government's role is limited to the granting of subsidies in major projects, tax incentives, and loans.

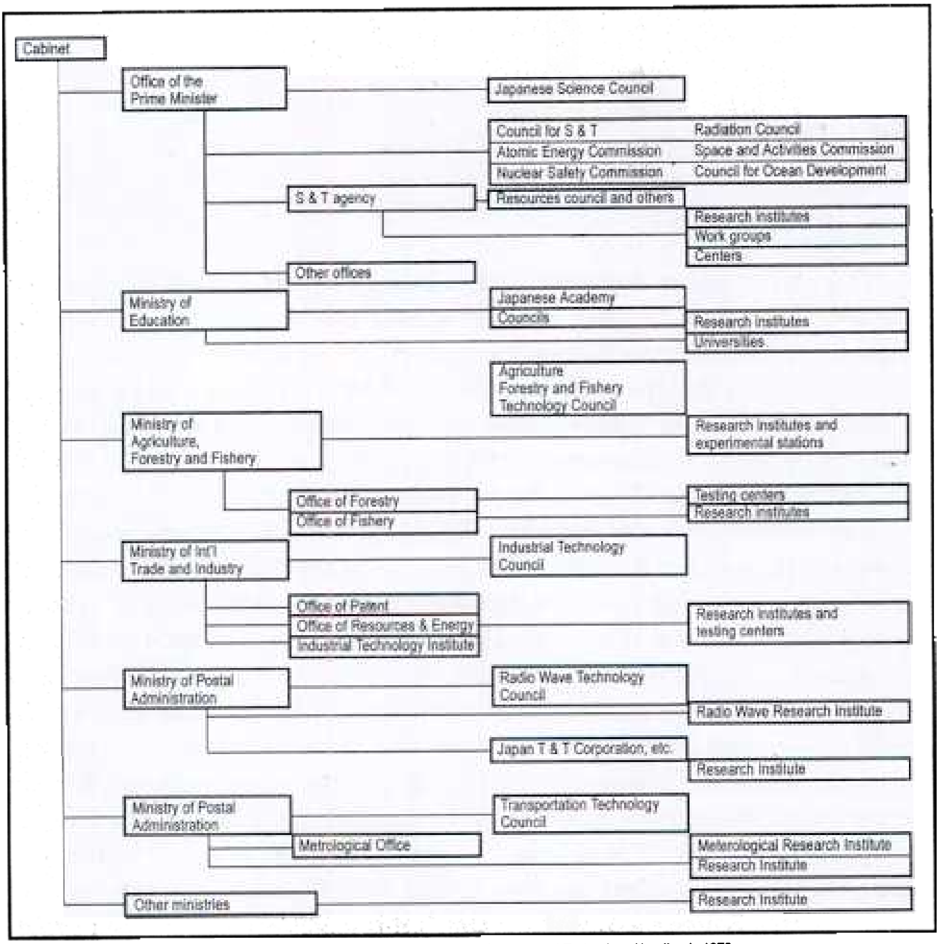
As the policymaking body, the CST proposed to the Prime Minister in 1971 the following science and technology goals (Choi 1983):

a. Apply science and technology to the country's social and economic needs as a means of promoting their advancement;
b. Promote science and technology after laying down their foundations; and
c. Promote basic science.

In 1977 the same council proposed the following as the basic goals of Japan's science and technology policy:

a. Secure a stable supply of resources and their economization;
b. Search for appropriate solutions to environmental and industrial safety problems;
c. Improve public health and medical systems;
d. Promote pilot science and technology projects; and
e. Foster technology power to promote international cooperation and strengthen the nation's international competitiveness.

Figure 12. Science and Technology Administrative Structure of Japan



Source: Choi, 1983. Original source: Science and Technology Agency (Japan), *Science and Technology Handbook*, 1979

III

Philippine Experience in Science and Technology

Patterns of Growth

The Philippine economic growth has been described as dismal in the last two decades. It went through a "roller-coaster ride" in the 1980s and 1990s (Figure 13). The early 1980s saw the economy growing at 3.5 percent. In the period 1984 to 1985, the economy contracted by a significant -14.6 percent in real terms. This economic collapse was brought about by the political turmoil arising from the assassination of a major political opponent of the Marcos administration. When Corazon Aquino took over the presidency in 1986, the economy bounced back strongly with a high growth rate of 6.8 percent in 1988. However, this was not sustained. The economy started to take a dip thereafter because of a number of reasons, foremost of which were the series of military coup attempts, natural calamities, electric power crisis, and unfavorable international economic environment. But when Fidel V. Ramos was elected to the presidency in 1992, the economy recovered again, attaining a growth of about 6 percent in 1996. The familiar problem of unsustainability of growth surfaced anew when the economy started sliding in the succeeding years. Mainly because of the Asian financial crisis that broke out in mid-1997 and the drought brought about by the El Nino phenomenon in 1998, the economy again contracted. There was a slight recovery though in 1999, but at the rate the political situation is deteriorating at present,[10] this might not be sustained based on the last 20 years of the country's boom-bust growth track record. Indeed, the economic prospects for the Philippines do not look promising.

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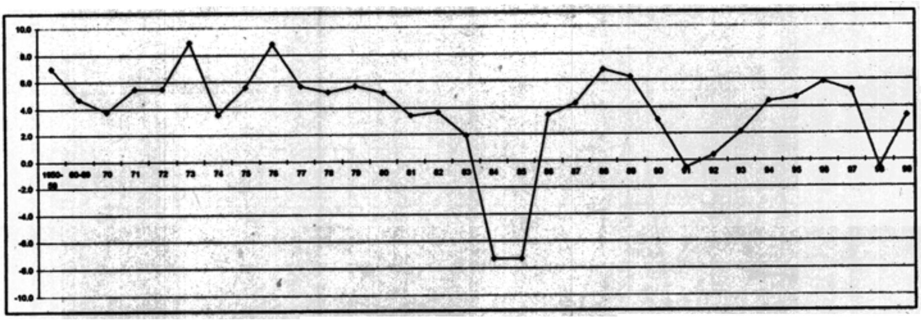
[10] On January 20, 2001 the Vice-President was sworn into the Office of the President because of graft and corruption charges against the elected president whose term of office was supposed to end in 2004.

Figure 13. Real GDP Growth (%), Philippines

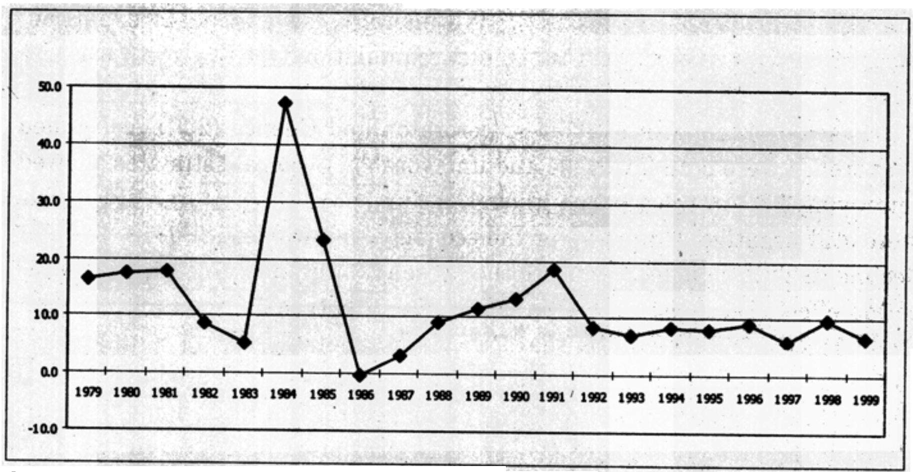


Source: *Philippine National Income Accounts, various issues*

Indeed, the Philippine economy is moving along a boom-bust growth cycle. While it may be true that the political instability is a major factor behind this, the weak economic structure also contributed significantly to this pattern of growth. Figure 14 shows the high inflation rate during the period. Inflation peaked to almost 50 percent at the height of the economic crisis in the mid-1980. In 1991, inflation surged again. High inflation during the period was caused mainly by macroeconomic mismanagement, as indicated by huge government budget deficit and unsustainable accumulation of both foreign and domestic debts.

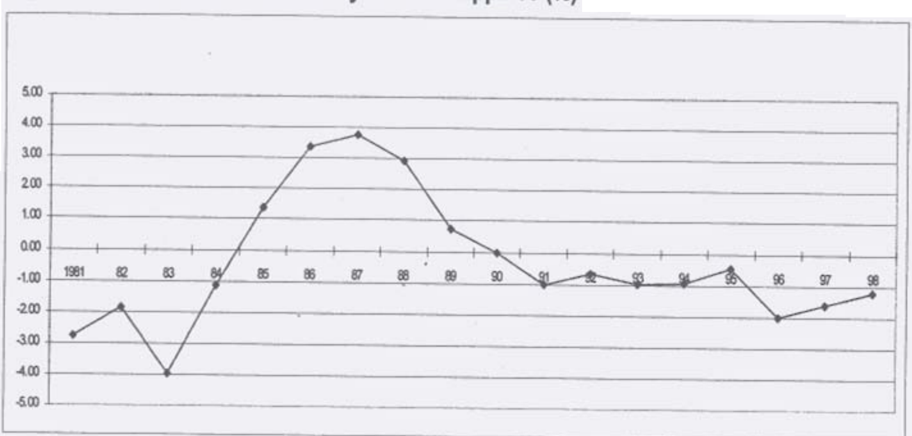
Figure 15 shows estimates of TFP. Except in the second half of the 1980s, TFP estimates were negative. In the 1990s TFP estimates were all negative as well. The sectoral TFP analysis of Cororaton and Cuenca (2001) shows a clear example of uncoordinated and policy failures in the Philippines, which created unfavorable resource allocation effects, weak economic fundamentals, and less growth. Their analysis indicates that it was the service sector that pulled down the overall TFP growth. Furthermore, they found that although the contribution of TFP was negative for the whole economy, there was actually an improvement during the 1990s. From a negative contribution during the 1980s, it made a slightly positive contribution during the 1990s. Based on their sectoral TFP analysis, the pattern for agriculture was similar: from negative TFP contribution in the 1980s to positive contribution in the 1990s. For mining, manufacturing, and utilities the contribution of TFP growth was

Figure 14. Inflation in the Philippines (%)



Source: Selected Philippine Economic Indicators, various issues

Figure 15. Total Factor Productivity in the Philippines (%)



Source: Cororaton and Cuenca, 2000

positive during the two decades. However, there was a significant slowdown during the 1990s relative to the 1980s. Generally, for nontradables, particularly the service-related sectors, capital accumulation type of growth was evident.

Based on their TFP estimates, Cororaton and Cuenca (2001) concluded that trends were both favorable and unfavorable. Sectoral estimates showed improving TFP in the 1990s, although a number of the sectoral TFP levels were still negative. However, for the economy as a whole, 1990 saw a slight decline in TFP. This may indicate the presence of unfavorable resource allocation effects because of the capital accumulation type of growth in the nontradable sectors, particularly the service-related ones, relative to the rest of the sectors in the economy. One factor that could have triggered this capital accumulation type of growth was the prolonged real appreciation of the currency in the face of an aggressive trade reform program in the first half of the 1990s. This kind of an economic environment is usually not conducive to production activities, both for domestic consumption and exports. In a period when capital inflow is massive (in mid-1990s, as will be pointed shortly), nontradable sectors like the real estate sector becomes an attractive destination of capital.

Table 30 shows the investment pattern during the period. Similar to the output growth path, a dip in the investment ratio occurred in the mid-1980s. However, there was a significant improvement in the 1990s. One of the major factors behind this was the surge in net foreign direct investments. However, a major part of this investment went to the real estate sector because of policy failure, as pointed out above, and therefore the impact on productive capacity was minimal since some of the real estate investments were speculative in nature. These consisted of investments in condominiums and other high-rise structures and buildings. On the other hand, net portfolio investment picked up during the same period. But they were highly speculative as well, because when the Asian financial crisis broke out in 1997, these investments evaporated immediately.

Savings are not adequate to finance investments. Figure 16 shows that the savings rate[11] has always been below the investment rate. It was only in three instances when the savings rate surpassed the investment rate: in

[11] "Savings rate" here refers to the gross national savings computed using the resource gap formula, that is, gross domestic investment plus current account balance net of official transfers.

Table 30. Investments in the Philippines

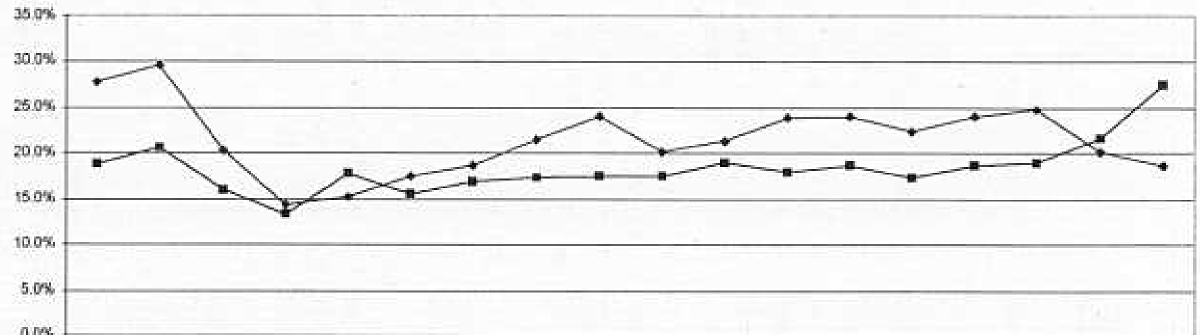
	GFCF/GDP(%)[1]	Net foreign direct investment (m US$)	Net portfolio investment (m US$)
1982	27.2	132	(115)
1983	28.9	221	(109)
1984	22.3	122	(105)
1985	16.5	49	(32)
1986	16.1	146	(6)
1987	16.5	362	(36)
1988	18.0	983	3
1989	20.6	559	284
1990	22.9	528	(48)
1991	19.8	529	125
1992	21.0	675	62
1993	22.4	864	(52)
1994	23.0	1,289	269
1995	23.0	1,361	248
1996	24.4	1,338	2,142
1997	25.8	1,113	(1,027)
1998	23.1	1,592	(1,003)
1999	21.9	871	449

Source: Selected Philippine Economic Indicators, various issues
[1] Gross fixed capital formation/Gross domestic product

1986, 1988 and 1999. In these years, investments were low because of economic recession. For sure, this is one major economic fundamental where the Philippines should improve on to make the economic activities viable. Certainly, this is difficult to achieve in an atmosphere of political instability.

However, significant structural changes have been taking place since the 1950s. Table 31 shows that agriculture sector captured 34.7 percent of production in 1950. Through the years, this share declined, so that by 1998 it was only 17.4 percent. The share of industry increased during the period when the government embarked on an import substitution policy. From a share of 27.1 in 1950, it increased to 38.8 percent in 1980. Similarly, the share of the manufacturing sector increased from 16.1 percent in 1950 to 25.7 percent in 1980. Seemingly, one indicator of failure of industrialization in the Philippines is the declining share of industry, particularly the manufacturing sector, in the last two decades. The shares declined to 31.8 percent in 1998 for industry in general and to 21.8 percent for manufacturing in particular. Over this long period, the share of the service sector increased from 38.2 percent in 1950 to 51.3 percent in 1998.

Figure 16. Investment and Savings Rates in the Philippines



	1982	83	84	85	86	87	88	89	90	91	92	93	94	95	96	97	98	99
Investment Rate	27.9%	29.6%	20.3%	14.4%	15.2%	17.5%	18.7%	21.6%	24.2%	20.2%	21.3%	24.0%	24.1%	22.5%	24.0%	24.8%	20.2%	18.6%
Savings rate	18.8%	20.6%	15.9%	13.3%	17.7%	15.6%	16.9%	17.3%	17.6%	17.5%	19.1%	17.9%	18.7%	17.4%	18.8%	19.0%	21.6%	27.5%

Source of basic data: Selected Philippine Economic Indicators, various issues

Table 31. Philippine Sectoral Gross Domestic Product (percentage share)

Sectors	1950	1960	1965	1970	1975	1980	1985	1990	1995	1998
Agriculture	34.7	26.5	27.2	29.5	30.3	25.1	24.6	21.9	21.6	17.4
Industry	27.1	31.3	31.1	31.9	35.0	38.8	35.1	34.5	32.1	31.3
Manufacturing	16.1	24.5	23.6	24.9	25.7	25.7	25.2	24.8	23.0	21.8
Services	38.2	42.2	41.7	38.6	34.7	36.1	40.4	43.6	46.3	51.3
Total	**100.0**	**100.0**	**100.0**	**100.0**	**100.0**	**100.0**	**100.0**	**100.0**	**100.0**	**100.0**

Source: Economic and Social Statistics Office, National Statistical Coordination Board

Table 32 shows the structure of our employment. Generally, a similar pattern is observed in the sectoral share of employment. There was a clear movement from agriculture to the service sector. More striking is the pattern of employment in the manufacturing sector, which has stagnated at around 10 percent of total employment in the last 40 years. This labor movement could have aggravated the pressing problem of poverty in the country because of low productivity in the service sector. De Dios (1993) observes that "the decline in the share of agriculture in employment has been significant; but since the industrial share has stagnated, it is services, a large part of which is in the so-called 'informal sector', which served as the receptacle for labor shed by agriculture but which industry failed to absorb. The lack of employment opportunities condemns the majority of the labor force to jobs with low productivity and poor pay."

One must also note the significant changes that have taken place in the export sector in the last three decades. The share of the semiconductor industry surged from zero in 1970 to 48 percent of total merchandise export receipts in 1999 (Table 33 and Figure 17). If finished electrical machinery is included, the total share is more than half of the total exports. However, the value-added component of semiconductor exports is very thin because only labor contribution comes from local sources. All the rest comes from foreign sources. In fact, the semiconductor industry in the Philippines is only at the assembly stage. The production process has to progress and to move up the ladder for it to contribute significantly to the economy. And there can be sizeable room for growth in this area because of the advent of information technology.

Garments used to be a major export item, but their share has declined since 1990. The shares of agriculture-based exports have also been declining such as sugar, coconut-related crops, banana, as well as mining-related commodities like copper.

Table 32: Philippine Sectoral Employment (percentage share)

Sector	1960	1965	1971	1975	1980	1985	1990	1995	1998
Agriculture	61.2	56.7	50.4	53.5	51.6	49.3	44.5	43.4	39.2
Industry	12.6	14.3	15.7	15.2	15.5	14.3	15.9	16.1	16.4
Manufacturing	12.1	10.9	11.5	11.4	10.9	9.7	10.5	10.2	9.7
Services	26.2	29.0	33.9	31.3	32.9	36.4	39.5	40.5	44.4
Total	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0

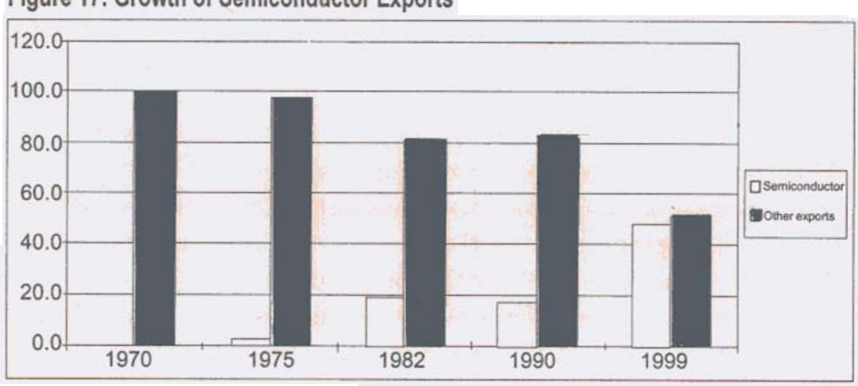
Source: *Labor Force Survey*, Department of Labor and Employment, various issues

Table 33. Philippine Exports (percentage share of major items)

	1970	1975	1982	1990	1999
Semiconductors and electrononic microcircuits	0.0	2.0	19.0	17.2	48.3
Finished electrical machinery	0.0	0.0	0.0	0.0	7.5
Garments	3.4	3.8	10.9	21.6	6.4
Crude coconut oil	8.8	10.0	7.5	3.8	0.7
Bars, rods of copper	0.0	0.0	0.9	3.5	0.7
Gold from copper ores	0.2	3.4	2.5	1.1	0.6
Banana and plantations	0.4	3.2	0.7	1.8	0.7
Copper concentrates	16.7	9.4	0.0	2.6	0.1
Shrimps and prawns	0.0	0.3	1.4	2.7	0.4
Canned pineapple	2.0	1.5	1.5	1.1	0.2
Iron agglomerates	0.0	0.0	6.3	1.0	0.2
Centrifugal sugar	16.7	25.3	3.4	1.1	0.2
Copra oil, cake, and meal	1.3	1.5	2.1	0.6	0.1
Others	50.5	39.6	43.8	41.8	34.0
Total	100.0	100.0	100.0	100.0	100.0

Source: Economic and Social Statistics Office, National Statistical Coordination Board

Figure 17. Growth of Semiconductor Exports



All told, the economic as well as the political environment in the Philippines is generally not conducive to a sustained growth. Although major economic reforms are underway, the relentless political squabbles among different quarters are in fact taking a heavy toll on the economy.

The Importance of R&D in the Philippines

In the Philippines, Austria (1998) and Cororaton and Abdula (1999) conducted a regression analysis of some possible determinants of TFP in the Philippines. Highlighting these at this point will put the discussion on technology-related issues in proper perspective.

The first study considered TFP of the entire economy as the dependent variable in the regression, while the second looked at TFP of the manufacturing sector. In Austria's paper, TFP of the entire economy was regressed against trade and investment policy indicators. The indicators included tariff rates, share of exports to GDP, share of imports to GDP, foreign direct investments (FDI), and inflation. Both tariff and import shares were used to capture the trade liberalization program of the government through reduction in tariff and nontariff barriers. FDI is one major vehicle for transferring technology from abroad, thus its inclusion in the analysis would attempt to capture transfer of technology. Inflation is a "catch-all" indicator of economic instability. High inflation means macroeconomic instability. Normally, economic instability discourages the adoption of productivity-enhancing programs (like R&D) and investment.

The regression results show a statistically significant effect of exports on TFP growth (Table 34). The two major exports of the Philippines are garments and semiconductors, which comprise more than 60 percent of the total merchandise exports. These exports are highly import-dependent in terms of raw materials and technology. In fact, they are closely tied up with foreign buyers through consignment. Thus, the growth in exports could also be a vehicle of technology transfer.

Contrary to the general expectation, imports have a negative effect on TFP. There are two possible explanations for this. First, in the regression, total imports were considered. Imports of machinery and equipment, which usually embody new production techniques and technology, are only a fraction of the total. Thus, the inclusion of the total imports might have captured other effects also. Second, the unavailability of skilled workers who could adequately operate the new machines and equipment might have led to their inefficient use, thus causing lower productivity.

Table 34. Determinants of TFP Growth in Manufacturing

Dependent Variable: TFP Growth of Manufacturing	Results: Coefficients and test of significance
Constant	5.316 (27.267)
Exports (-1)	0.148 (8.581)
Imports (-1)	-0.519 (-18.522)
(Tariff)	-1.740 (-33.438)
Wage	-0.126 (9.353)
DRD(-1)	0.101 (-9.353)
PDI(-2)	0.005 (-14.081)
INF	-0.153 (14.081)
INF(-1)	-0.468 (-23.088)

Adusted R2	=	0.997
DW	=	0.65
+-Stat	=	448.63

Where:

Exports(-1): Real growth of exports, lagged one period

Imports(-1): Real growth of imports, lagged one period

D(tariff): Period differential of average nominal tariff rates

Wage: Growth of research and development expenditure as % of GDP, lagged one period

FDI(-2): Foreign direct investment

INF: Inflation

INF(-1): Inflation, lagged one period

Source: Cororaton and Abdula, 1999
T-values are in ( ).

Tariff rate has a negative effect on TFP, although the coefficient is not statistically significant. Effective rate of protection (EPR) could have been the more appropriate indicator of tariff liberalization, but time series on EPR was not available. However, Austria (1998) cites other studies showing that when protection is reduced at a moderate rate, the rise in productivity is highest; and when protection is reduced at an excessively fast rate or when it is not reduced at all, the rise in productivity is lowest.

FDIs have positive effects on one of the estimated equations but are not statistically significant (Equation 1 in Table 35). While it may take some time before FDI brings about productivity effects, the result of incorporating a one-year lag in FDI yields a positive effect (Equation 2). However, the effect of including both the total FDI and FDI in manufacturing shows a significant positive effect of total FDI on TFP growth but a significant negative effect of FDI on manufacturing (Equation 3). Austria (1998) explains the negative effect of manufacturing FDI by citing the fact that multinational companies are oriented toward the global market, thus there may be less room for adaptation of technology to the local economy on a wider scale. Lastly, inflation, which is a catch-all variable of macroeconomic instability, has a significant negative effect on TFP.

In a similar exercise, Cororaton and Abdula (1999) conducted a regression analysis of some possible factors affecting manufacturing TFP. The factors included the estimated TFP of the manufacturing sector, exports, imports, tariff, minimum wages, R&D, foreign direct investment, and inflation. The variables entered the analysis either as ratios to GDP or in first difference or both.

All estimated coefficients are statistically significant (Table 34). Exports ratio positively affects manufacturing TFP. The reason discussed above with regard to export may also apply here, i.e., exports could be one channel through which foreign technology is transferred to the local economy. This is because

Table 35: Determinants of Total Factor Productivity, 1960-1996

Dependent Variable: TFP Growth of Philippine Economy	Equation (1)	Equation (2)	Equation (3)
Constant	-0.016	-0.018	0.034
	(-0.69)	(-0.76)	(0.53)
Share of exports to GDP	0.005	0.005	0.008
	(3.41)*	(3.31)*	(2.41)**
Share of imports to GDP	-0.003	-0.002	-0.004
	(-2.27)**	(-1.99)***	(-3.46)*
Tariff rate	-0.83E-04	-0.015E-03	-0.002
	(-0.07)	(-0.13)	(-0.99)
Inflation rate	-0.002	-0.002	-0.002
	(-4.62)*	(-4.91)*	(-5.46)*
Foreign direct investment (FDI)	0.12E-05		0.33E-05
	(-1.26)		(2.14)
FDIt-1		0.11E-05	
		(1.01)	
FDI in manufacturing			-0.11E-05
			(-1.85)**
DW Statistics	1.94	1.89	2.09
Adjusted R2	0.53	0.52	0.67

Note: t-values are in ( ). *, **, and *** indicate significance at 1, 5, 10 percent levels, respectively.
Source: Austria, 1998

of the close tie-up between the major exporters in the Philippines with foreign direct buyers. However, similar to the previous results, the same negative effect of imports on TFP manufacturing results.[12]

That tariff has negative effects on manufacturing TFP implies that a reduction in the tariff protection would result in productivity improvement (probably due to efficiency gain from a competitive environment). FDI has a significant positive effect on TFP.

Minimum wage, usually wage rate for unskilled labor, in the Philippines is legislated. The results show that an increase in minimum real wage decreases productivity, which is generally expected. Usually, a wage system that is not based on productivity is inefficient. Inflation, an indicator of economic instability, negatively affects productivity. High inflation occurs in an economic system with lots of uncertainty. This prevents organizations from pursuing productivity-enhancing programs.

R&D as a percent of GDP has a positive effect on TFP. This fact has an important policy implication because, usually, technological change cannot be realized without technological infrastructure. Furthermore, the effectiveness of technology transfer requires distinct activities and investments, and a certain level of technological development in the country to minimize the cost of implementing the new technology and to maximize its productivity once in place. Normally, the technological development of a country depends upon R&D investments and on the efficiency of its R&D institutional system.

Patterns, Developments and Policies in R&D and Technology

Level of R&D efforts. Cororaton (1999) surveyed a UNESCO-based data on R&D indicators for 91 countries and found that the Philippines ranked very low in terms of R&D effort. Table 36 shows that out of 91 countries, the Philippines placed 73rd in terms of number of scientists and engineers per million population. It has only 152 scientists and engineers per million population. This is way below the maximum of 6,736 scientists and engineers per million population. In terms of R&D expenditure-to-GNP ratio, the Philippines is at the 60th place with a ratio of 0.2 percent in 1992. This is far below the maximum of 3 percent.

[12] The negative coefficient showed up when capital import was included in the regression instead of total imports. Although the reason behind this may be unclear, the authors attribute this to the inappropriateness of technology adopted by industries. Such technology that functions merely as input entails no significant effect on domestic science and technology (Yap 1989).

Table 36. PCGNP, SE/MP, and GERD/GNP (in 91 countries of the world)

No.	Country	Per capital GNP (US$)	Scientists/ engineers per million population	Gross expenditure on R& D/GNP (%)	Year
1	Switzerland	37,930	2,409	.8	1989
2	Japan	34,630	5,677	3	1992
3	Denmark	27,970	2,341	1.8	1991
4	Norway	26,390	3,159	1.9	1991
5	United States	25,880	3,873	2.9	1989
6	Germany (Federal)	25,580	2,882	2.8	1989
7	Iceland	24,630	3,067	1.1	1991
8	Austria	24,630	1,146	1.4	1989
9	Sweden	23,530	3,081	2.9	1991
10	France	23,420	2,267	2.4	1991
11	Belgium	22,870	1,856	1.7	1990
12	Singapore	22,500	1,284	0.9	1984
13	Netherlands	22,010	2,656	1.9	1991
14	Canada	19,510	2,322	1.6	1991
15	Kuwait	19,420	924	0.9	1984
16	Italy	19,300	1,366	1.3	1990
17	Finland	18,850	2,282	2.1	1991
18	United Kingdom	18,350	2,334	2.1	1991
19	Australia	18,000	2,477	1.4	1990
20	Israel	14,530	4,836	2.1	1984
21	Brunei Darusalam	14,240	91	0.1	1984
22	Ireland	13,530	2,801	0.9	1988
23	Spain	13,440	956	0.9	1990
24	New Zealand	13,350	1,555	0.9	1990
25	Qatar	12,820	593	0	1986
26	Cyprus	10,260	205	0.2	1992
27	Portugal	9,320	599	0.6	1990
28	Korea, Republic	8,260	1,990	2.1	1992
29	Argentina	8,110	350	0.3	1888
30	Greece	7,700	53	0.3	1986
31	Slovenia	7,040	2,998	1.5	1992
32	Seychelles	6,680	281	1.3	1983
33	Uruguay	4,660	686	-	-
34	Mexico	4,180	226	0.2	1984
35	Gabon	3,880	189	0	1987
36	Hungary	3,840	1,200	1.1	1992
37	Trinidad and Tobago	3,740	240	0.8	1984
38	Chile	3,520	364	0.7	1988
39	Malaysia	3,480	326	0.1	1992
40	Czechoslovakia	3,200	3,247	1.8	-
	a. Former		4,190	3.3	1989
	b. Czech Republic		3,248	1.8	1992
41	Mauritius	3,150	361	0.4	1992
42	South Africa	3,040	319	1	1991
43	Brazil	2,970	391	0.4	1985
44	Venezuela	2,760	208	0.	1992
45	Russian Federation	2,650	5,930	1.8	1991
46	Croatia	2,560	1,970	-	1992
47	Turkey	2,500	1,977	0.8	1991
48	Thailand	2,410	173	0.2	1991

Table 36 continued

No.	Country	Per capital GNP (US$)	Scientists/ engineers per million population	Gross expenditure on R& D/GNP (%)	Year
49	Poland	2,410	1,083	0.9	1992
50	Costa Rica	2,400	539	0.3	1992
51	Latvia	2,320	3,387	0.3	1992
52	Fiji	2,250	...	0.3	1986
53	Belarus	2,160	3,300	0.9	1992
54	Peru	2,110	1273	0.2	1981
55	Ukraine	1,910	6,761	-	1989
56	Tunisia	1,790	388	0.3	1992
57	Colombia	1,670	39	0.1	1982
58	Paraguay	1,580	248	0.03	-
59	Jamaica	1,540	8	0	1986
60	Jordan	1,440	106	0.3	1989
61	El Salvador	1,360	19	0	1992
62	Lithuania	1,350	1,278	-	1992
63	Ecuador	1,280	269	0.1	1990
64	Romania	1,270	1,220	0.7	1992
65	Bulgaria	1,250	4,240	0.7	1992
66	Guatemala	1,200	99	0.2	1988
67	Uzbekistan	960	1,760	-	1992
68	Philippines*	*950*	*152*	*0.2*	*1992*
69	Indonesia	880	181	0.2	1988
70	Macedonia (FYR)	820	1,258	-	1991
71	Bolivia	770	250	1.7	1991
72	Egypt	720	458	1	1991
73	Sri Lanka	640	173	0.2	1991
74	Congo	620	461	0	1984
75	Senegal	600	342	-	1981
76	Honduras	600	138	-	-
77	China	530	1,128	0.5	1991
78	Guyana	530	115	0.2	1982
79	Guinea	520	264	-	1984
80	Pakistan	430	54	0.9	1990
81	Central African Rep.	370	55	0.2	1990
82	Benin	370	177	0.7	1989
83	Nicaragua	340	214	-	1987
84	India	320	151	0.8	1990
85	Nigeria	280	15	0.1	1987
86	Guinea-Bissau	240	263	-	-
87	Vietnam	200	334	0.4	1985
88	Nepal	200	22	-	1980
89	Madagascar	200	22	0.5	1988
90	Burundi	160	32	0.3	1989
91	Rwanda	80	12	0.5	1985

*1992 Figures computed by DOST.

Basic source of data: UNESCO, *Statistical Yearbook, 1995;* UNESCO, *World Science Report,* 1996; World Bank, *World Development Report, 1996*

The low number of scientists and engineers reflects the general tendency of the educational system in the Philippines to produce non-technical graduates. Table 37 shows that while the Philippine educational system produces a very high number of tertiary graduates, the number of post-baccalaureate science and engineering students as a percent of post-baccalaureate students is low. In column 6 of the table, the Philippines ranks the lowest in the list with a ratio of only 8.65. This is far from the second lowest of 20.76 percent, which is for New Zealand. The highest is China with a ratio of 74.26 percent.

There is in fact a dilemma in the present educational system because of the educational "mismatch." While there is a great demand for technical and engineering graduates by local industries, private tertiary schools continue to produce nontechnical graduates. This is indeed a big policy problem. One of the reasons for this problem is that private schools prefer not to go into technical courses because of the high laboratory requirement, which is capital-intensive. Non-technical courses are less laboratory-intensive and therefore less capital-intensive.

Furthermore, in a recent survey conducted by the Philippine Institute for Development Studies (Cororaton et al. 2000) on the R&D activities of government agencies and state universities and colleges (SUCs), it was

Table 37. Tertiary Education Across Selected Pacific Rim Countries

Country	(1)	(2)	(3)	(4)	(5)	(6)
China (1991	2,124,121	0.17	80,459	3.79	59,748	74.26
	2,683,035	2.13	85,263	3.18	54,167	63.53
Japan (1989)	2,683,035	2.13	85,263	3.18	54,167	63.53
South Korea (1991)	1,723,886	3.83	92,599	5.37	28,479	30.76
Australia (1991)	534,538	2.92	92,903	17.38	26,876	28.93
Singapore (1983)	35,192	1.13	1,869	5.31	532	28.46
Malaysia (1990)	121,412	0.58	4,981	4.1	1,251	25.12
Thailand (1989)	765,395	1.24	21,044	2.75	4,928	23.42
New Zealand (1991)	136,332	3.78	13,792	10.12	2,863	20.76
Philippines (1991)	1,656,815	2.39	63,794	3.85	5,520	8.65

Column Definition:
(1) Number of students at tertiary level
(2) Number tertiary students as percent of population
(3) Number of postbaccalaureate students
(4) Postbaccalaureate as percent of tertiary students
(5) Number of postbaccalaureate science and engineering students
(6) Postbaccalaureate science and engineering students as percent of postbaccalaureate students

Basic Source of data: UNESCO *World Science Report*, 1996 observed that more than 30 percent of R&D personnel with Ph.D. degrees are in social sciences, while only less than 10 percent are in the fields of engineering and technology (Figures 18 and 19). About 15 percent are in agricultural sectors.

S&T background, policies and programs. Philippine S&T's long history can be traced back to the early American colonial period during which the Bureau of Science was created. The American government, through the Bureau, formed the Philippine S&T. However, the coverage was very limited, as it mainly focused on agriculture, health and food processing. Thus, because of the colonial economic policy, the development of industrial technology was largely neglected. Yet it proved to be an effective training ground for Filipino scientists following the establishment of the public school system during the same period.

The setting up of the public school system paved the way for the creation of the University of the Philippines (UP) system and the various S&T-related agencies and laboratories.

Major shifts in the direction of Philippine S&T took place right after the proclamation of independence in 1946. Among others, the Bureau was reor-

Figure 18. Ph. D. Personnel (Full-Time), Field of Activity (all respondents, percent distribution)

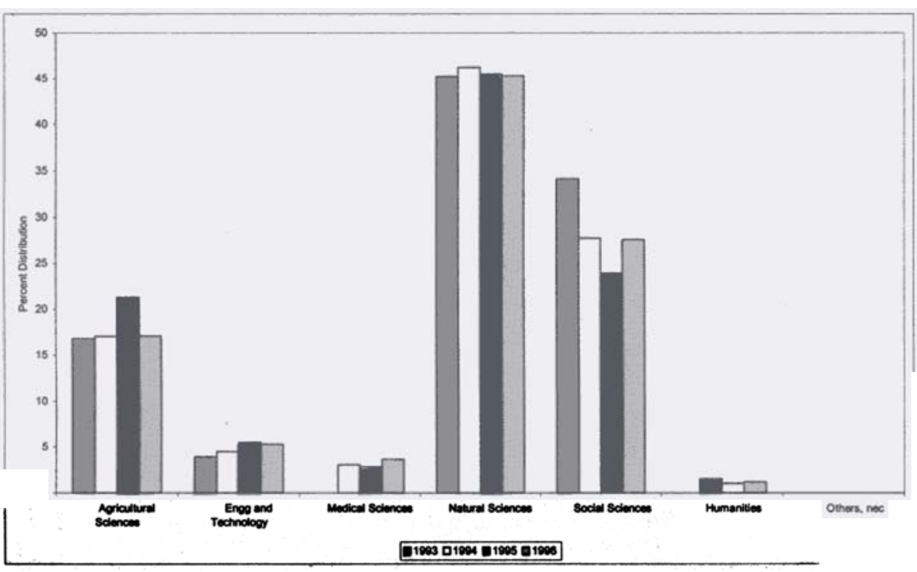
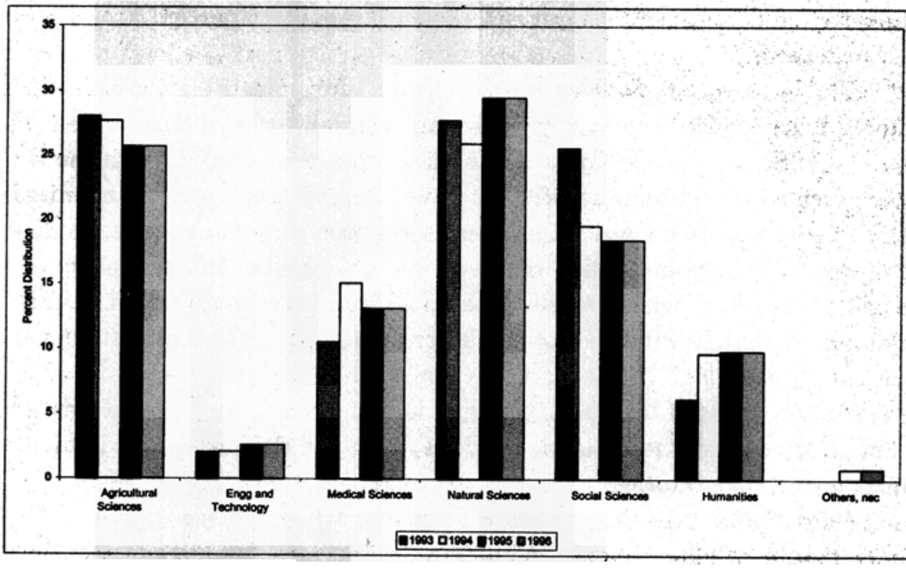


Figure 19: Ph. D. Personnel (Part-Time), Field of Activity (all respondents, percent distribution)



ganized into an Institute of Science and placed under the Office of the President. Despite these changes, its impact on the economy was marginal. The Institute suffered from lack of support, planning, and coordination. In fact, the Bell Mission's Recommendation specifically stated that the Institute had no capability to support S&T development for lack of basic information, neglect of experimentation and small budget for R&D activities.

Major shifts in the 1950s and 1960s focused on S&T institutional capacity building. This was done through the establishment of infrastructure-support facilities like new research agencies, and manpower development. Again, the effects were not significant. The usual problems of lack of coordination and planning, especially in technology, prevented the system from performing effectively its functions. This was evident in the unplanned activities of the researchers within the agencies, who, on their own, looked for technologies and scientific breakthroughs that were commercially viable. Without clear research directions, researches were done for their own sake, leaving to chance the commercialization of the output.

In response to these problems and the need to generate S&T products and processes that would be beneficial to the country, focus was redirected toward applied research in the 1970s. Furthermore, in the 1980s, research utilization was given stronger emphasis. This led to the reorganization of the bureau into the National Science and Technology Authority (NSTA) in 1982. The NSTA, which had eight R&D institutes and support agencies, was intended to address the need for an effective and efficient utilization of the results of R&D activities through greater commercialization of outputs. A significant innovation under the reorganization was the creation of the S&T council system, which was responsible for the sectoral formulation of policy and strategies and allocation of funds. There were four councils under the system: the Philippine Council for Health Research and Development (PCHRD), Philippine Council for Industry and Energy Research and Development (PCIERD), Philippine Council for Agriculture, Forestry, and Natural Resources Research and Development (PCARRD), and the National Research Council of the Philippines (NRCP). Later, the NRCP was replaced by the Philippine Council for Aquatic and Marine Research and Development (PCAMRD) and the Philippine Council for Advanced Science and Technology Research and Development (PCASTRD).

In the mid-1980s, the regional offices for S&T promotion and extension were established to further hasten the development of S&T. There was also a conscious effort to assist and encourage the local inventors through institution building and support measures. A national center for excellence for the basic sciences was established in the University of the Philippines. As well, the scientific career system was created to attract scientists to a career path that would professionalize and upgrade the status of scientists. Furthermore, institutional frameworks were organized to strengthen the linkages between the academe and the private sector.

Thus, the creation of the councils and research institutes under the NSTA showed a clear shift in S&T policy from being "technology push-oriented" to one that was based on the "demand-pull" strategy, where user and market demand served as the basis for conducting R&D/S&T programs. Thus, scientists and researchers were placed under R&D programs deemed to have high demand potentials.

After the EDSA Revolution in 1986, the NSTA was reorganized into what is now called the Department of Science and Technology (DOST) by virtue of Executive Order 128. The DOST, being headed by a Cabinet Secretary, was mandated to provide overall direction for all S&T efforts by formulating and implementing policies, plans, programs and projects geared toward S&T development.

To ensure a more effective delivery of certain functions, the DOST was further restructured through the establishment of the Technology Application and Promotion Institute (TAPI), its implementing arm that would push for the commercialization of technologies and marketing of the technology services of other operating agencies of the department. In addition, the Science Education Institute (SEI) was set up to formulate plans for the development of S&T education and training. Moreover, the Science and Technology Information Institute (STII) was established to serve as the information arm of the department through the development and maintenance of an S&T data bank and information networks.

The National Institute of Science and Technology was reorganized into the present Industrial Technology Development Institute to undertake applied R&D, transfer R&D results to end-users, and provide technical, advisory and consultancy services in the fields of industrial manufacturing, mineral processing, and energy. Entry into the advanced technology areas was formalized with the creation of the Advanced Science and Technology Institute (ASTI). In line with this, additional S&T councils, namely, the PCASTRD and the PCAMRD, were created to further strengthen the Council system.

Furthermore, the DOST reinforced massive technology transfer activities. Specific interventions were initiated through various programs such as the Comprehensive Technology Transfer and Commercialization (CTTC) program. The CTTC was intended to serve as a mechanism for identifying and pushing concrete results of R&D toward productive application. The initial phase of the program that covered the period 1989 to 1992 included a number of technologies whose utilization was envisioned to create substantial impact on the national socioeconomic development process and on the lives of many Filipinos, in general. The program covered areas such as financing, technology packages and training centers.

In most R&D institutes, technology transfer units were established to carry out the added responsibility of transferring completed researches. Provincial S&T centers were established to help ensure the efficient transfer of technologies to the provinces. S&T services were also provided to supplement R&D and technology transfer. Such services included the upgrading of testing, standardization and quality control services as well as various forms of technical assistance and consulting services. Assistance to investors was also provided. This consisted of patenting assistance for inventions with commercial potentials; assistance in the availment of financing for commercially viable inventions; marketing assistance; support to pilot-plant operations for selected top-priority technologies for commercialization; and support to the upgrading of inventions, expertise and capabilities.

R&D institutes undertook contract researches to foster collaboration among the institutes, the private sector, and the academe. Furthermore, funding assistance to technology developers through tie-ups with financing institutions like the Development Bank of the Philippines, Technology Livelihood Resource Center, Land Bank, and Private Development Corporation of the Philippines was also initiated.

Incentives were provided under the Omnibus Investment Law for certain R&D and S&T activities in the private sector. Some of the major incentives included income tax holiday; duty-free importation of capital equipment; deduction from taxable income for the acquisition of the necessary infrastructure and facilities in less developed areas; access to bonded manufacturing/trading warehouse system; and permission to employ foreign experts.

To facilitate the transfer of foreign technology, science parks were set up. These parks were also intended to serve as the vehicles for university interaction with private industry; to develop new knowledge-based industries and strengthen existing ones; and to provide a propitious environment for innovation and contract research. Moreover, technology business incubators were initiated in certain areas to assist the transfer and commercialization of technologies by helping ensure the survival and successful growth of new technology firms by providing them with appropriate marketing, financial, technical and management assistance.

A presidential task force on S&T was formed in 1988, specifically to deal with the overall problems confronting R&D and S&T development in the country and to formulate an S&T development plan that would support the national development goal of attaining a newly-industrializing-country status by the year 2000. The task force was composed of the DOST, Department of Agricultre (DA), Department of Trade and Industry (DTI), Department of Transportation and Communications (DOTC), the Presidential Adviser on Public Resources, and three academic institutions directly involved in S&T. In March 1989 the task force submitted a report to the President on the development of 15 leading edges to steer the country to industrial development. These were (1) aquaculture and (2) marine fisheries, (3) forestry and (4) natural resources, (5) process industry, (6) food and (7) feed industry, (8) energy, (9) transportation, (10) construction industry, (11) information technology, (12) electronics, (13) instrumentation and control, (14) emerging technologies, and (15) pharmaceuticals.

To attain the objectives set in the S&T Master Plan (STMP), the government pursued the following strategies: (a) modernize the production sectors through massive technology transfer from domestic and foreign sources; (b) upgrade the R&D capability through intensified activities in high priority sector and S&T infrastructure development such as manpower development; and (c) develop information networks, institutional building, and S&T culture development (Tables 38 and 39).

During the Ramos administration, the DOST initiated a Science and Technology Agenda for National Development (STAND Philippines 2000), which embodied the country's technology development plan in the medium term, in particular, for the period 1993 to 1998. The STAND identified as priority investment areas seven export winners, 11 domestic needs, three supporting industries, as well as the coconut industry, which was singled out for its strategic importance. The export winners identified were computer software; fashion accessories; gifts, toys, and houseware; marine products; metal fabrication; furniture; and dried fruits. The domestic needs included food, housing, health, clothing, transportation, communications, disaster mitigation, defense, environmental protection, manpower development, and energy. Because of their linkages with the above sectors, the three additional support industries included in the list of priority sectors were packaging, chemicals and metals.

Recently formulated is the S&T framework plan entitled "Competence, Competitiveness, Conscience: The Medium-Term Plan of the Department of Science and Technology (1999-2004)." Although it has not yet been fully analyzed, its six flagship programs are worth mentioning: (1) comprehensive program to enhance technology enterprises: (2) integrated program on clean technologies; (3) establishment of a packaging R&D center; (4) expansion of regional metrology centers; (5) S&T intervention program for the poor, vulnerable, and disabled; and (6) comprehensive S&T program for Mindanao. The vision and direction of the plan is novel, yet it provides no specific implementing rules and guidelines.

Some general insights. There are two key reasons why S&T/R&D policies in the Philippines suffered major setbacks: (a) underutilization of S&T for development, as reflected in the low quality and low productivity of the production sectors; and (b) weak linkage between technology generation, ad-

Table 38. Summary of Science and Technology Policies by Strategy

1. Modernization of Production Sectors
   - 1.1 Generation and active diffusion of employment-oriented and high value-added technologies
   - 1.2 Emphasis on developmental R&D toward commercialization
   - 1.3 Proper selection and acquisition of essential and appropriate technologies.
   - 1.4 Adaptation, absorption and mastery of imported technologies
   - 1.5 Dissemination of appropriate technologies
   - 1.6 Increasing accessibility to S&T information and services
   - 1.7 Reducing environmental degradation and mitigating adverse impacts of natural hazards

2. Upgrading of R&D Activities
   - 2.1 Establishing R&D priorities
   - 2.2 Development of local materials and indigenous technologies
   - 2.3 Stimulation of private sector participation
   - 2.4 Reducing environmental degradation and mitigating Adverse impacts of natural hazards

3. Development of S&T Infrastructure
   - 3.1 Development of high-quality S&T manpower in growth areas
   - 3.2 Expansion of S&T education and training
   - 3.3 Development of S&T institutions
   - 3.4 Development of an S&T culture

Source: Eclar, 1991

Table 39. Summary of Science and Technology Policy Programs in the Philippines

Policy and Program	Brief Description
Modernization of the production sectors A Comprehensive Technology Transfer and Commercialization Program (CTTC) B Support programs to the CTTC	The CTTC serves as a mechanism to link technology generators and users. It aims to hasten the process of industrialization through commercialization of technologies whose utilization is envisioned.
B-1 Production of technology packages	Provision of info and economic feasibility studies
B-2 Investors' fora	Venues for technology generators
B-3 National and regional technology fairs	Organized to showcase new technologies for transfer
B-4 Technology financing programs	Funding assistance to technology
B-5 Information services	Information packages on mature technologies
B-6 DOST training centers	Conduct technology training
B-7 Regional and provincial S&T centers	Ensure the transfer of technologies
B-8 DOST Academy Technology Business Entrepreneurship Development Program	Link between DOST and the academe for technology commercialization

Table 39 continued

C Technology business incubators	Assist new technology firms through technical, financial, and marketing assistance
D Science and technology parks	Facilitates the transfer of university-industry interaction in advanced technology
E Global search for technology	Search and acquisition of commercial technologies abroad
F Program of assistance to investors	Assistance in patenting, financing, and marketing
2 Upgrading of R&D activities	
A R&D Priority Plan (export winners, basic domestic needs, and coconut industry)	Indication of preferred areas of R&D
B Grant-in aids program	Support of R&D activities
C Contract research program	Sponsored research with other agencies
D R&D incentive programs	Incentives for the conduct of R&D activities
3 Development of R&D infrastructure	Graduate and undergrad scholarship program in priority areas
A Manpower Development Program in Science and Engineering	Dev't of the grade school network serving as feeder schools for HS and technical schools
B Grade school and secondary school level	Dev't of vocational and technical schools in the industrializing areas
C Vocational and technical education	
D Scientific Career System (SCS)	Career path for scientists that will develop their technical expertise
E Utilization of Filipino professionals and workers	Employment of Filipino expatriates
F Recognition of S&T efforts	Conferment of the rank and title of National Scientists
G Balik-scientist program	Taking advantage of trained Filipino scientists and engineers through information exchange
H Development of S&T culture	Promotion of science consciousness and innovativeness
I Organizing and strengthening of S&T networks and institutions	Strengthening of S&T sectoral network and establishment of new S&T institutions and mechanisms

aptation and use. S&T development also suffers from underinvestment in terms of manpower training, technological servicing, R&D facilities, and financial resources.

The weak linkage can be attributed to (a) slow commercialization of technologies due to a weak delivery system; (b) poor linkages between S&T organizations and industry and other government agencies; and (c) low appreciation of R&D due to the short-term perspective of private and government agencies.

To identify ways of improving the delivery system and the commercialization of R&D output, Eclar (1991) investigated some of the underlying factors behind such an improvement. One of these was user participation. This means that successful commercialization is promoted when a user with a specific need has been identified at the start of the project. The user generally maintains an interest in the progress of the research and takes on the commercialization of the results at the completion of the research project to meet his previously identified need. This is reinforced when the user's interest in the project is translated into support or cost sharing. Another important factor identified by the study was pilot testing. Demonstration of the technical viability of the technology in a semi-commercial scale helps convince an industry user to start off commercialization. Commercial success is promoted when the user himself has provided material inputs to the pilot test.

In spite of the express importance of S&T and R&D development in the Philippines and the series of well-intentioned strategies, the state of S&T and R&D development remains far behind those of other Asian countries by any measure. One reason behind this is the low private sector participation in R&D activities. Most developed countries boast of a healthy R&D partnership between the public and private sectors. For instance, the bulk of R&D expenditure that originates from the private sector in Japan is 83 percent, Korea 82 percent, Taiwan 65 percent, Singapore 62 percent, and Thailand 40 percent. Contrast these with the Philippines' measly 20 percent from the private sector, or even less.

Aside from underinvestment in R&D, the Philippines also suffers from the shortage of S&T manpower. For lack of good employment opportunities in the domestic economy, braindrain of technical personnel as well as S&T professionals results. In 1992 the Philippines had only 15,610 personnel engaged in R&D activities, representing 152 individuals per million population. The UNESCO puts the critical mass of S&T personnel at 380 per million population to facilitate the application of technology.

The STMP and STAND 2000 have too many identified areas to support with too little financial resources. One wonders how much attention was given to the consideration of the viability of their implementation. This is in view of the weak linkage between planning and budgeting, and little consideration for budget availability in the plan formulation stage. With insufficient budget allocation, the DOST either had to cancel or to reduce its financial support for specific S&T development programs and projects.

R&D is crucial in a country's development process, yet some economic agents are hesitant to pursue it because of the high risks involved in R&D activities, particularly the uncertain outcomes of certain R&D undertakings. Then, too, there is the high incidence of spillover or externality, which is hard to appropriate. Thus, to push R&D activities to the frontier, government interventions are critical. But the formulation of the type of government intervention needed is a delicate thing to do, and oftentimes controversial, because of imperfect information. Wrong policy formulation could put to waste limited government resources. However,.the experiences of Korea and Taiwan show that proper targeting of industries and tailor fitting of R&D incentive structure could work very well if accompanied by a sound human resource development. In fact, coordination in these two areas and implementation of a good program for a continuous manpower training and development have propelled and sustained the economic growth of these two Asian countries.

Poor coordination and lack of coordinated planning in relation to R&D are two other major problems confronting the innovation and technology sector in the country. In various government departments and agencies, surveys and interviews indicate a seemingly chaotic and confusing system of institutional arrangements for lack of focus on strategic sectors and programs. Furthermore, as Magpantay (1995) argues, the DOST system has become so complex, having expanded its size way beyond its ability to perform its functions effectively. The Department is doing a lot of unfocused and ill-planned activities through its different councils and institutions. Certainly, this leads to institutional inefficiencies. A reorganization of the structure of the Department is therefore required.

R&D Gaps in the Philippines

The poor productivity performance in the Philippines, as highlighted above, is due largely to the gaps in R&D. There are national as well as sectoral gaps in terms of expenditure, budget, and manpower.

Gaps at the national level. Based on an econometric study, Cororaton (1999) estimates the magnitude of R&D gaps at the national level. R&D gaps are defined as those factors that have prevented the economy from operating to the fullest in terms of productivity. These factors could be either in the form of (a) low R&D investments and inadequate R&D manpower; (b) institutional weaknesses as a result of poor system, management and leadership; (c) policy lapses and failures; or all three combined. But in the estimation, only the first two have been considered because of insufficiency of data.

The results indicate that the resulting R&D expenditure gap is 0.5778. This means that the R&D expenditure-GNP ratio would have to increase by 0.5778 for the Philippine TFP to reach the TFP frontier. The average R&D

expenditure-GNP ratio during the 1980s was 0.1667 percent. Thus the total R&D expenditure-GNP ratio needed to reach the frontier is 0.1667 + 0.5778 = 0.7445. This is a sizeable increase from the current level, but lower than what has been proposed in S&T Bill (House Bill No. 2214)—1 percent of GNP.

Applying this ratio to the 1997 GNP of P2,527 billion will yield a total R&D expenditure of roughly P18.8 billion. This R&D investment gap is substantial, considering that the present level of R&D spending is approximately P3 billion. It is also impossible for the government to fill this gap because of the budgetary impact that it is likely to create.

The government, though, has other equally important and pressing needs, especially in the area of basic infrastructure like market roads, bridges and port, and of social sectors like education and health. Furthermore, it may be totally inefficient to reallocate limited government resources to R&D activities because of the institutional inefficiencies in the R&D system as well as in the S&T structure. David et al. (1999), for example, argues that while agricultural research continues to be underfunded, "efficiency of public sector research funding has been significantly lowered by the misallocation of limited budgetary resources, as well as by institutional weaknesses of the agricultural research system." Thus, unless these institutional weaknesses are addressed, additional government funding into R&D will only go to waste.

In some progressive countries, the bulk of R&D investment comes from the private sector. The challenge therefore is how to encourage the private sector to participate in R&D activities. It is also important to identify the necessary infrastructure, incentive system and investment safeguards that will enable the said sector to do its own R&D.

In terms of manpower, it was observed that the gap is around 197 scientists and engineers per million population. The average ratio for the 1980s was only 108. For the Philippine TFP to reach the gap, it needs R&D manpower (108 + 197 = 305) per million population.

Sectoral gaps and problems. Technology-related issues and problems are generally similar across sectors. They largely focus on four major problems: (a) underinvestment in R&D; (b) lack of adequate and technically capable R&D manpower; (c) institutional weaknesses; and (d) policy failures. Below is a brief discussion on the following sectors: agriculture, fishery, manufacturing, education, and health.

Agriculture[13]

Underfunded research in agriculture. The agricultural sector has performed poorly since the 1980s. David et al. (1999) attribute this poor performance to a number of factors, one of which is the inadequate public support services, particularly in agricultural research and development. According to David et al., "The agricultural research system was severely underfunded with public expenditures in the early 1980s, representing only 0.3 percent of agriculture gross value-added, in contrast to an average of 1 percent among developing countries and 2 to 3 percent among developed countries (Table 40). In fact, only 5 percent of the total public expenditure for agriculture has been allocated for agriculture research; whereas the ratio of budgetary outlay for price stabilization programs alone was in the range of 10 percent over the past decade (Table 41)."

David et al. (1999) identify other equally important gaps, if not more important ones, in agricultural research. These are (a) inefficiencies caused by the misallocation of research resources within the sector (e.g., across research program areas and ecological regions) and (b) weaknesses in the institutional framework of the research system, including the flawed organizational structure,

Table 40. Agricultural Research Intensity Ratios (RIR) of Selected Countries

Country	RIR (%)	Reference (year)
Philippines	0.33	1992
Thailand	1.40	1992
Indonesia	0.27	1990
Malaysia	1.06	1992
China	0.43	1993
Taiwan	4.65	1992
Australia	3.54	1992
India	0.52	1990
Pakistan	0.47	1992
Bangladesh	0.25	1992
Sri Lanka	0.36	1993
South Korea	0.56	1993
Japan	3.36	1992
Developing countries	1.00	
Developed countries	2-3	

Source: David et al., 1999

[13] Largely based on the paper of David et al., 1999

Table 41. Distribution of Public Expenditures for Agriculture and Natural Resources by Policy Instruments, 1987-1994 (%)

	1987-94	1994
Agrarian reform	26	24
Natural resources and environment	23	23
Agriculture	51	53
Irrigation (NIA)	12	8
Price stabilization (NFA)	9	13
Research	4	5
Extension	7	9
Coconut development	2	2
Livestock	1	2
Others	17	15

Source: David et al., 1999

lack of accountability, fragmentation of research, incentive problems, instability in leadership, and weak linkage between research and extension.

Misallocation of research resources. Using the congruence rule, which defines the optimal research resource allocation across commodity program areas as proportional to the respective commodity value-added or value of production shares (in other words, given a total budget for agricultural research, the research intensity ratio, i.e., research expenditure as a ratio of the value-added, should be equal across commodity research program areas), David et al. (1999) have found that the "allocation of research expenditures across commodities and regions has been highly incongruent to their relative economic measured in terms of gross value-added contribution of the commodity." They add that "in particular, relatively greater research budgets are provided for minor commodities such as cotton, silk and carabao, and too little to major ones such as corn, coconut, and fisheries. Furthermore, Mindanao regions are relatively neglected in terms of research budgets of the DA and SUCs compared to regions in Luzon and to a lesser extent to those in the Visayas." "While congruency," they say, "does not strictly coincide with optimal research resources allocation, the differences in research intensity ratios observed among commodities and across regions cannot be explained by possible differences in cost research (probability of research success, etc.), future market potential nor equity considerations."

David et al. (1999) identify other indications of misallocation of resources and institutional weaknesses in agricultural research, namely:

(1) Overly high share of personal salaries. Personal salaries (PS) on the average tend to be disproportionately high at 58 percent, while maintenance and other operating expenses (MOOE) make up about 36 percent and capital outlays (CO) only 6 percent of the total expenditure for agricultural research. In more developed countries, where salary rates are much higher, the distribution of expenditures is 40 percent for PS, 40 percent for MOE, and 20 percent for CO.

Generally, in almost all research agencies in the Philippines, the shares of PS are high; at least 50 percent. In a number of commodity research agencies and SUCs, the shares can be as high as 70 to 80 percent. PhilRice, however, is an exception. The structure of expenditure is 40 percent for PS, 50 percent for MOE, and 10 percent for CO. This allows for a more efficient utilization of its manpower and physical facilities, as well as promotes more systematic and long-term research planning.

UP Los Baños, which undertakes the bulk of agriculture research, has also the same expenditure structure, with PS share as high as 70 percent. Moreover, research projects under the different institutes, centers, and research units of the university are primarily driven by the priorities of external donors, who contribute about half of the research funding. As such, the effectiveness of research is constrained by uncertain and short-term nature of funding, even though the university may have the most capable scientists in the country in different fields in agriculture.

The overly high share of PS in the Philippines may reflect overstaffing, bureaucratic rigidities and poor planning.

(2) Unfocused projects. An analysis of the work and financial plans and projects that have been completed in the Philippines indicates that research projects are highly fragmented and short-term in nature. Research findings and outputs are not carried to future researches or used for extension to benefit the clientele. This is because there is no adequate system or clear mechanism whereby research findings are fully transferred to the targeted end-users. Also, there are no systems where researches are continued on a long-term and continuous basis. Thus, generally, research projects are not problem-oriented.

(3) Absence of clear networks among SUCs. Ponce (1998) argues that SUCs are basically "independent from each other despite their hierarchical designations as national multi-commodity research centers, regional research stations, and cooperating stations. The national multi-commodity research cen-

ters' (UPLB, Central Luzon State University, Visayas State College of Agriculture, and University of Southern Mindanao) linkage to the regional and cooperating stations are ad hoc in character, and project-related. There exists no institutionalized linkage resulting from clearly defined complementary functions."

(4) Absence of a clear network between DA and its attached agencies. Ponce (1998) also argues that the DA research system consists of national experiment stations operated by (a) various bureaus such as Bureau of Plant Industry, Bureau of Animal Industry, Bureau of Fisheries and Aquatic Resources, and Bureau of Soils and Water Management (BSWM); (b) attached agencies such as PhiRice, Philippine Carabao Center, Philippine Coconut Authority, Sugar Regulatory Administration, and Fiber Industry Development Authority; (c) regional integrated centers under the regional offices of the DA; and (d) regional outreach stations. As with the SUCs, "there exists no clear functional delineation between the national stations and the regional experiment stations, and between the regional and the provisional stations. Each station exists independently of each other in terms of programs, even within the DA proper. Thus, national centers do not exactly orchestrate the national research and development programs of their assigned commodities."

(5) Absence of a clear linkage with the private sector. Ponce (1998) also cites the weak linkage between the private sector and the larger community of research stations. Most private research centers exist principally to meet the needs of the companies that established them. As such, they do not interact with the rest of the research community, dominated essentially by the government sector, except for a few privately operated research centers that perform public services such as the Twin Rivers Research Center. There is also no mechanism whereby this link could be fostered.

(6) Other institutional gaps. Other institutional weaknesses cited by Ponce (1998) are (a) the lack of well-defined and institutionalized mechanism for collaboration among R&D subsystems; and (b) the inefficient funding system and lack of accountability. The present funding system is still very much like the old project-approach one, where research outputs are essentially in the forms of research reports. This weakens the system of program approach and leads to the distortion of national priorities. Furthermore, the present funding approach gives rise to a much-diffused structure of research implementation where responsibility is difficult to pinpoint.

Manpower gaps. In terms of R&D manpower profile in agriculture, the authors find that the problem is not in terms of number but in the relatively low level of scientific qualification of the agriculture research system. This is particularly true in both the DA and the Department of Environment and Natural Resources (DENR) research agencies. The very low ratios of technical manpower resources with advanced degrees at the DA and DENR does not compare quite favorably with similar institutions in some Asian countries like Malaysia, Indonesia, and even Bangladesh.

On the other hand, the quality of research manpower in SUCs is not uniformly or always significantly better. Although the share of manpower in SUCs may be higher than in agencies, there is a big and worsening problem of inbreeding. Furthermore, local scientists who were trained and educated abroad are not generally attuned to recent developments or frontier international knowledge. Also, there is a big gap in the quality of faculties and researchers in UPLB and other SUCs.

Fisheries Sector[14]

This sector is important not only because it has direct impact on national health and nutrition (i.e., fish is the source of about 75 percent of the total animal protein requirement of the country, or more than poultry and livestock combined), but also because its structure, particularly on the supply side, is directly affected by what has been happening in the environment. To a certain extent, the fisheries sector can be one output indicator of what has been happening in the environment.

Israel (1999) points out that the weak performance of the fisheries sector has been the result of several interrelated problems, the top three of which are (a) resource depletion in coastal waters due to overfishing and destructive fishing, as manifested by the deterioration of important fish stocks and species and the degradation of ecosystems; (b) large-scale environmental damage, as evidenced by the destruction of coral reefs and mangroves in marine areas and the pollution of major river lakes; and (c) proliferation of industrial, agricultural, commercial, and domestic activities, which discharge pollutants into marine waters, contributing to the deterioration of ecosystems and rendering marine food potentially harmful for consumption.

[14] Based on the paper of Israel, 1999

R&D is important to the development of the fisheries sector, particularly to its long-term survival. Primarily, R&D is crucial to generating new information and technologies that can increase output above the current low and dwindling levels. The responsibility of managing and coordinating fisheries R&D in the Philippines has been the task of the PCAMRD. The Council, which is under the DOST, is tasked to plan, monitor, as well evaluate fisheries R&D. The paper of Israel (1999) discusses the R&D structure of the fisheries sector. Furthermore, PCAMRD interacts with two government agencies whose R&D scope covers the fisheries sector. These agencies are the Bureau of Agricultural Research (BAR) of the DA and the Ecosystem Research and Development Bureau (ERDB) of the DENR. They are mandated to coordinate all researches of the regional offices and line agencies within their respective departments. The BAR covers fisheries research because fisheries are administratively classified under the agricultural sector. The ERDB does so since aquatic resources form part of the natural resource base and therefore falls under DENR.

Institutional gap and issues. Israel (1999) has found that one of the biggest gaps which results from the present institutional arrangement is the weak coordination and poor collaboration among government agencies. As stated, the PCAMRD is the agency tasked to manage and coordinate overall fisheries R&D while the BAR and the ERDB coordinate fisheries research of the regional offices and line agencies of their respective departments. Because of the similarity in functions and constituency, potential overlapping was observed to exist among the three agencies. To address this problem, the agencies delineated their functions by drawing up Memoranda of Agreements (MOAs). Implementation of these agreements, however, has been hampered by poor collaboration. In particular, in violation of the MOAs, the agencies do not actually jointly review all research proposals submitted for funding. Furthermore, collaboration is weak or lacking in several activities and strong only in one aspect.

Aside from poor collaboration, another crucial institutional problem deals with a possible duplication of tasks between PCAMRD and BFAR arising from the existing Fisheries Code. The Code reconstituted the BFAR from a staff to a line bureau under the DA and assigned it the function of formulating and implementing a Comprehensive Fishery Research and Development Program. To effect this program, the law created a new agency within BFAR, the National Fisheries Research and Development Institute (NFRDI) as its main research arm. Among the functions of this agency are the establishment of a national infrastructure that will facilitate, monitor, and implement various research activities of the fisheries sector; and the establishment, strengthening, and expansion of a network of fisheries-related communities through effective communication linkages nationwide. These functions of the BFAR and the NFRDI may duplicate those of the PCAMRD. For one, the responsibilities of formulating and implementing an overall plan for fisheries R&D and coordinating its implementation are the mandates of the council. For another, the Council has already established a network of research institutions, the National Aquatic Resources Research and Development Systems, to serve as an implementing arm for fisheries R&D. At a larger scale, the duplication of functions in the R&D programs in the fishery and agriculture sectors has been noted by the Agricultural Commission.

The issue of which agency and department should manage, coordinate, and implement R&D has been a long-running one. At present, this question is far from settled and creates a lot of bureaucratic and institutional inefficiencies.

Capability issues. Capability issues surrounding R&D in fisheries include (a) low investment (including public, private, as well as foreign investments); (b) funding problems such as their untimely release; (c) manpower shortage; and (d) poor maintenance of existing capital.

(a) Low public investment. The most glaring resource-related problem in R&D is historically low government funding that agriculture as a whole receives (Tables 42 and 43). In developed countries, the average public investment in agriculture R&D is about 2 percent of their agricultural gross value added (GVA). In contrast, only about 0.019 percent of GVA is allocated locally. The Philippines has the lowest R&D allocation for agriculture in Asia.

For fisheries, in particular, allocation averages only about 0.102 percent of fisheries value-added, which is close to what agriculture is getting. However, the fisheries R&D budget is only about 3.6 percent of the total expenditure for agriculture and natural resources R&D combined. Thus, compared to agriculture and natural resources, the fisheries sector is getting the worst end of the deal in the sharing of government funds.

A look at disaggregate data indicates not only low government funding for fisheries R&D but also an uneven government allocation among institutions. In 1996, among the NARRDS members, the budget as ratios to the total number of researchers and projects differed widely (Tables 44 and 45). It can be seen also that the ratios of budget to the number of researchers and projects were low for many institutions, including some zonal centers.

Table 42. Public Expenditures for R&D in Agriculture and Natural Resources, Gross Value-added in Agriculture, including Fishery and Forestry, and Research Intensity Ratios (RIR), 1992-1996

	1992	1993	1994	1995	1996
Research expenditures (₱ million)[a]					
a. w/out SEAFDEC	800	853	1,065	1,290	1,554
	(1,027)	(1,121)	(1,400)	(1,638)	(1,919)
b. with SEAFDEC	881	958	1,184	1,434	1,707
	(1,228)	(1,248)	(1,540)	(1,815)	(2,114)
2. Gross value-added (₱ million)	281,748	303,415	355,612	392,954	449,080
3. Research intensity ratio (%)					
1a/2	0.28	0.28	0.3	0.33	0.35
	(0.36)	(0.37)	(0.39)	(0.42)	(0.43)
1b/2	0.31	0.32	0.33	0.36	0.38
	(0.40)	(0.41)	(0.43)	(0.46)	(0.47)

[a] Refers to direct budgetary outlay. Figures in parentheses refer to total research expenditure, including external grants from local and foreign sources.
Source: Israel, 1999

Table 43. Public Expenditures for R&D in Agriculture, Natural Resources, and Related Environmental Issues (in million pesos)

	1992	1993	1994	1995	1996	1997
DA	459.74	464.27	651.59	758.84	913.9	na
	(501)	(524)	(696)	(842)	(1030)	(na)
DENR	68.98	78.6	109.69	120.8	149.33	213.97
	(85)	(93)	(123)	(133)	(161)	(218)
ERDB	23.03	21.04	15.65	15.58	21.78	64.16
	(32)	(30)	(24)	(23)	(32)	(66)
ERDS	43.35	55.08	92.12	99.65	122.21	149.81
	(50)	(60)	(97)	(104)	(123)	(152)
PAWB	2.6	2.48	1.92	5.57	5.34	10.69
	(3)	(2)	(2)	(6)	(5)	(11)
DOST	81.25	100.52	103.01	153.08	180.13	228.42
	(150)	(160)	(188)	(217)	(277)	(378)
PCARRD	42.82	56.24	56.88	88.66	105	127.1
	(62)	(84)	(99)	(123)	(168)	(180)
PCAMRD	9.6	11.01	10.96	9.09	18.61	19.4
	(50)	(26)	(40)	(32)	(46)	(89)
FPRDI	28.83	33.27	35.16	55.33	56.53	81.93
	(38)	(50)	(49)	(62)	(62)	(110)

Table 43. continued

	1992	1993	1994	1995	1996	1997
SUCs	189.57	209.42	200.88	257.72	309.68	331.71
	(292)	(344)	(393)	(446)	(452)	(496)
UP System	91.71	94.54	80.61	113.66	130.52	128.05
	(183)	(203)	(239)	(261)	(235)	(237)
UPLB	87.32	90.69	76.73	108.88	123.69	120.36
(162)	(196)	(219)	(251)	(223)	(224)	
UPMSI	3.7	3.7	3.15	3.97	5.67	5.79
	(na)	(na)	(na)	(na)	(na)	(na)
UP VISAYAS	0.69	0.15	0.73	0.82	1.17	1.9
	(18)	(3)	(17)	(7)	(6)	(7)
Other major universities	81.98	95.88	95.53	112.57	142.97	165.84
	(92)	(122)	(129)	(153)	(181)	(221)
Other universities	15.88	18.99	24.74	31.49	36.19	37.82
	(na)	(na)	(na)	(na)	(na)	(na)
SEAFDEC	81.25	104.72	118.75	143.25	153.48	185.27
	(101)	(127)	(140)	(177)	(195)	(213)
Total w/out SEAFDEC	**799.54**	**852.81**	**1,065.17**	**1,290.44**	**1,553.04**	**na**
	(986)	**(1060)**	**(1356)**	**(1555)**	**(1919)**	**(na)**
Total with SEAFDEC	**880.79**	**957.53**	**1,183.92**	**1,433.69**	**1,706.52**	**na**
	(1087)	**(1188)**	**(1496)**	**(1732)**	**(2114)**	**(na)**

Source: David et al., 1999
Numbers in ( ) include external grants.

To address the problem of low budget for agriculture and fisheries R&D, the Agriculture and Fisheries Modernization Act stipulated that allocations be increased to at least 1 percent of GVA by the year 2001. For its part, the Fisheries Code legislated the creation of a special fund for fisheries R&D in the initial amount of P100 million. The AFMA is mute regarding the sharing of funds between agriculture and fisheries. Assuming that allocation will be proportionate to output contribution, the budget for fisheries should jump substantially from its current levels. It is doubtful whether the planned increases in allocations will fully materialize soon given the mounting fiscal deficits.

Low private investment. Data on private investment in fisheries R&D are scarce. This is understandable given the natural aversion of the private sector to divulging information. This notwithstanding, private entities are known to have been involved, one way or another, in R&D, especially in applied research and technology verification activities, where the likelihood of generating new technologies for immediate commercial application is high.

Table 44. Agency-Funded Fisheries R&D Projects of NARRDS Institutions, Budget: Researcher Ratio

Institution	No. of Researchers	Budget (P)	Budget: Researcher Ratio
DA-BFAR	61	3,754,000	61,541
DMMMSU	13	1,072,903	82,531
UPLB	9	3,373,580	374,842
UPV	44	2,193,075	49,843
MSU-Naawan	25	1,257,125	50,285
ZSCMST	15	790,000	52,667
DA-CAR	-	230,100	-
DA-Region1	2	1,007,000	503,500
DA-Region 2	10	889,000	88,900
DA-Region 4	-	4,572,000	-
DA-Region 5	-	2,180,046	-
DA-Region 6	-	785,000	-
DA-Region 8	-	415,000	-
DA-Region 11	-	902,044	-
DA-Region 13	-	310,000	-
DA-ARMM	-	87,000	-
DENR-Region 10	-	4,165,000	-
BU	-	543,000	-
CMU	2	11,000	5,500
CSC	-	341,000	-
CSU	18	548,040	30,447
CCSPC	-	1,461,033	-
CVPC	-	244,000	-
DOSCST	-	972,500	-
ISCOF	19	2,425,000	127,632
MMSU	17	100,000	5,882
MSU-SULU	-	590,488	-
MSU-TCTO	21	1,330,000	63,333
NIPSC	3	5,450,248	1,816,749
NMP	-	64,564	-
NVSIT	5	136,000	27,200
PALSU	-	1,110,000	-
PIT	-	308,000	-
PSPC	12	25,000	2,083
PSU	8	321,000	40,125
TONC	-	60,000	-
UEP	-	496,370	-
UPMSI	25	3,579,400	143,176
Average	**17**	**1,265,777**	**195,902**

- No data

Source: Israel, 1999

Table 45. Agency-Funded Fisheries R&D Projects of NARRDS Institution, 1996 Budget:Project Ratio

INSTITUTION	No. of Projects	Budget (P)	Budget: Project ratio
DA-BFAR	11	3,754,000	341,273
DMMMSU	30	1,072,903	35,763
UPLB	9	3,373,580	374,842
UPV	8	2,193,075	274,134
MSU-Naawan	7	1,257,125	179,589
ZSCMST	7	790,000	112,857
DA-CAR	4	230,100	57,525
DA-Region1	10	1,007,000	100,700
DA-Region 2	8	889,000	111,125
DA-Region 3	41	4,572,000	111,512
DA-Region 4	12	2,180,046	181,671
DA-Region 5	12	785,000	65,417
DA-Region 6	8	415,000	51,875
DA-Region 8	8	902,044	112,756
DA-Region 11	10	310,000	31,000
DA-Region 13	3	87,000	29,000
DA-ARMM	1	4,165,000	4,165,000
BU	3	543,000	181,000
CMU	1	11,000	11,000
CSC	4	341,000	85,250
CSU	6	548,040	91,340
CCSPC	4	1,461,033	365,258
CVPC	2	244,000	122,000
DOSCST	3	972,500	324,167
ISCOF	9	2,425,000	269,444
MMSU	12	100,000	8,333
MSU-SULU	1	590,488	590,488
MSU-TCTO	8	1,330,000	166,250
NIPSC	13	5,450,248	419,250
NMP	3	64,564	21,521
NVSIT	2	136,000	68,000
PALSU	4	1,110,000	277,500
PIT	3	308,000	102,667
PSPC	1	25,000	25,000
PSU	6	321,000	53,500
TONC	1	60,000	60,000
UEP	3	496,370	165,457
UPMSI	31	3,579,400	115,465
Total	**309**	**48,099,516**	**155,662**

Source: Israel, 1999

A lot of the private sector involvement in fisheries R&D is in aquaculture. During the rapid development of this industry in the last 20 years, private firms have been collaborating with national institutions and locally based international research agencies in the conduct of applied research, covering many commodities including prawn, tilapia, milkfish, crab, and other commercially profitable species.

In the commercial fisheries, private sector participation in R&D is limited since research in capture technologies usually requires larger investments and results are difficult to patent. Also, many research activities, such as stock and resource assessments, have social externalities that go beyond the interests of private operators and thus are better left to government and international research agencies to conduct. The common practice in the commercial fisheries has been to use imported technologies outright or modify to some extent said technologies to suit local requirements and needs.

In the municipal fisheries, private investment in monetary terms is low because of the poor economic condition of the municipal fishermen. However, manpower involvement in R&D is substantial among fishermen and their families, as seen in their participation in the conduct of numerous coastal resource management and similar projects undertaken by government and international agencies.

Available data show that the share of private investment in fisheries R&D is low (Table 46). To promote this type of investment, the AFMA encourages government research agencies to go into co-financing agreements with the private sector, provided that the terms and conditions of the agreements are beneficial to the country. For reasons already cited, the possibility of these agreements actually happening will be higher in aquaculture than in the commercial and fisheries subsectors.

Low foreign investment. Figures show that between 1988 and 1994, foreign funding for fisheries R&D comprised more than half of the total funding (Table 46). In recent years, however, this share has gone down (Table 47). By 1996, only 7 percent of the total funds of NARRDS institutions came from foreign sources (Table 49). Furthermore, funding was concentrated only in a few areas, mostly the environment and other priority areas.

Foreign funding is important because it is essentially a signaling mechanism. Low outside investment for domestic R&D could mean that local research institutions and their programs are not internationally competitive

Table 46. R&D Expenditures for Fisheries by Sector and Source of Funds, 1988-1994 (in million pesos)

Sector	Foreign	%	Government	%	Private sector	%	Grand total
Marine fisheries	218.45	73	75.78	25	3.08	1	297.31
Inland aquatic resources	60.73	38	98.08	61	1.17	0.7	159.98
Socioeconomics	4.67	19	20.35	81	-	-	25.02
Total	283.85	59	194.21	40	4.25	0.9	482.31

Source: Israel, 1999

Table 47. R&D Expenditures for Fisheries of Selected NARRDS Institutions, by Source of External Grants, 1992-1996 (in thousand pesos)

Institution	Funds	1992	1993	1994	1995	1996	Average	%
	Local	0	0	200	144	1,087	286	100
	Foreign	0	0	0	0	0	0	0
	Sub-total	0	0	200	144	1,087	286	100
DOST-PCAMRD	Local	12,310	8,140	18,780	19,060	23,200	16,298	60.25
	Foreign	28,060	6,760	10,660	3,670	4,610	10,752	39.75
	Sub-total	40,370	14,900	29,440	22,730	27,810	27,050	100
UPV	Local	15,553	2,409	13,531	2,804	3,472	7,554	64.86
	Foreign	0	0	17,356	2,873	237	4,093	35.14
	Sub-total	15,553	2,409	30,887	5,677	3,709	11,647	100
Total without SEAFDEC AQD	Local	27,863	10,549	32,511	22,008	27,759	24,138	61.92
	Foreign	28,060	6,760	28,016	6,543	4,847	14,845	38.08
	Total	55,923	17,309	60,527	28,551	32,606	38,983	100
SEAFDEC AQD	Local	0	0	0	0	0	0	0
	Foreign	3,150	3,550	3,770	8,490	8,040	5,400	100
	Sub-total	130,009	54,269	143,484	79,357	93,639	5,400	100
Total with SEAFDEC AQD	Local	27,863	10,549	32,511	22,008	27,759	24,138	54.39
	Foreign	31,210	10,310	31,786	15,033	12,887	20,245	45.61
	Total	185,932	71,578	204,011	107,908	126,245	44,383	100

Source: Cororaton et al., 2000

Table 48. Distribution of Manpower for Fisheries R&D

Agency	Ph. D.	MS	BS	ASSOC	Total	%
Zonal area for Northern Luzon (Region I, II, III and CAR)	11	57	25	-	93	12.3
Zonal area for Southern Luzon (Region NCR, IV and V)	20	45	131	12	208	27.59
Zonal Area for Visayas (Regions VI, VII, and VIII)	31	117	166	6	320	42.44
Zonal area for Northern Mindanao (Region X, XI and Caraga)	2	19	53	-	74	9.81
Zonal area for Southern Mindanao (Regions IX and XII)	3	21	35	-	59	7.82
TOTAL	67	259	410	18	754	100
%	8.89	34.35	54.38	2.39	100	

Source: Israel, 1999

Table 49. Distribution of the NARRDS R&D Program Budget

Commodity	Source of Funds		Total
	Local (P)	Foreign (P)	Budget
Export winners			
Seaweed	7,236,997	0	7,236,997
Crab	2,613,727	842,677	3,456,404
Tuna	225,000	0	225,000
Shrimp	1,605,739	0	1,605,739
Basic domestic needs			
Tilapia	2,664,975	0	2,664,975
Milkfish	80,903	0	80,903
Small pelagics	2,257,428	0	2,257,428
Environment	29,000,173	2,262,513	31,262,686
Other priority areas	14,837,104	1,500,000	16,337,104
Total	**60,522,046**	**4,605,190**	**65,127,236**

Source: Israel, 1999

and vice versa. Furthermore, in this time of economic crisis, foreign money may be the only viable way of increasing allocations. Be that as it may, the AFMA and Fisheries Code do not address the issue of international funding for R&D.

(b) Untimely release of funds. A commonly cited fund-related problem in fisheries R&D is the untimely release of government funds to institutions, programs, and projects. In fact, this constraint is true not only for R&D but also for other activities dependent on government support. In fisheries, it is acute because of the importance of time and season in the conduct of activities. Although there are no data that can be used to validate this, research activities are reported to be cancelled or haphazardly conducted because of delay in the release of funds. A review of the Fisheries Sector Program shows other problems in the management of government funds (Pacific Rim Innovation and Management Exports Inc. and ANZDEC Ltd. 1996), which has implications for fisheries R&D. These include the excessive control by the Department of Budget and Management (DBM) of a large proportion of program funds; the diversion of some funds to other activities not necessarily directly related to the program; the lack of coordination between the DBM and program administrators regarding fund utilization; and the lack of a financial monitoring system.

(c) *Shortage of manpower.* Earlier figures show that the NARRDS institutions have relatively limited R&D manpower at all levels (Table 48). They also indicate that personnel capability varies greatly between regions and programs and that senior personnel, especially those with doctorate degrees, are concentrated in a few institutions (Table 50). While the limited number of doctorate holders has been compensated, in some cases, by master's degree holders, it cannot be denied that more of the former are required in NARRDS institutions to provide organizational and research leadership.

A comparison of selected NARRDS and National Agriculture and Resources Research Development Network institutions suggests that the manpower in fisheries R&D is no more than 10 percent of that in agriculture although the percentage of Ph.D. holders is a bit higher (Table 51). This proportion is highly uneven and not reflective of the higher ratio of fisheries output to total agricultural production (Table 52). Also, the graduate to undergraduate ratio of fisheries R&D staff appears to be significantly lower compared to that of agriculture also.

Table 50. Manpower for Fisheries R&D of Selected NARRDS Institutions, 1998

Institution	Ph. D.	MS	BS	NI*	Total
DA-BFAR	2	21	42	1	66
DOST-PCAMRD	4	11	10	0	25
DMMMSU	1	6	15	0	22
UPLB	1	1	0	0	2
UPV	0	12	13	1	26
MSU-Naawan	4	19	13	0	36
MSU-Marawi	1	15	10	1	27
CLSU	1	7	2	0	10
UPMSI	3	2	20	0	25
BU	4	9	2	0	15
MMSU	1	2	4	0	7
PSU	0	3	1	0	4
Average without SEAFDEC AQD	2	10	13	0	25
SEAFDEC	21	43	1	0	65
Average with SEAFDEC AQD	1	7	7	0	15

*Means "not indicated"

Source: Cororaton et al., 2000

Table 51. Comparison of the Number of R&D Personnel in Selected NARRDS and NARRDN Institutions, 1995-1996

Institution	Ph. D.	MS	BS	Total	Graduate: Undergraduate
NARRDS					
UPLB	4	3	2	9	3.5
DMMMSU	1	9	3	13	3.33
UPV	15	13	16	44	1.75
MSU-NAAWAN	2	14	9	25	1.78
CLSU	1	10	0	11	0
UPMSI	15	6	4	25	5.25
ZSCMST	3	7	5	15	2
Average	5	9	6	18	2.52
NARRDN					
UPLB	53	206	225	484	1.15
USM	37	72	8	117	13.63
ViSCA	39	69	24	132	4.5
BSU	15	36	36	87	1.42
CMU	43	135	139	317	1.28
ISU	17	61	13	91	6
CSSAC	19	40	30	89	1.97
Average	32	88	68	188	4.28

Note: NARRDN stands for National Agriculture and Natural Resources Research and Development Network, the counterpart of NARRDS. NARRDS data are for 1996 while NARRDN data are for 1995. NARRDS data are specifically for fisheries R&D manpower only.

Source: Israel, 1999

Table 52. R&D Expenditure for Fisheries

	Year (1)	R&D in Fisheries (Pm) (2)	GNP (Pm) and Fisheries (Pm) (3)	GVA Forestry Fisheries (Pm) (4)	GVA (1)/(2)	(1)/(3)	(1)/(4)
1982	14.52	313,544	74,055	14,084	0.005	0.02	0.103
1983	14.67	363,268	82,545	17,580	0.004	0.018	0.083
1984	10.14	508,485	129,824	22,666	0.002	0.008	0.045
1985	15.82	556,074	140,554	27,058	0.003	0.011	0.058
1986	22.02	596,276	145,807	32,019	0.004	0.015	0.069
1987	18.07	673,130	163,927	31,256	0.003	0.011	0.058
1988	33.4	792,012	183,515	34,708	0.004	0.018	0.096
1989	37.03	912,027	210,009	36,460	0.004	0.018	0.102
1990	76.33	1,082,557	235,956	40,833	0.007	0.032	0.187
1991	67.74	1,266,070	261,868	47,276	0.005	0.026	0.143
1992	109.98	1,385,562	294,922	51,633	0.008	0.037	0.213
1993	119.49	1,500,287	318,546	57,533	0.008	0.038	0.208
1994	38.34	1,737,315	372,853	65,860	0.002	0.01	0.058
1995	63.89	1,970,519	412,965	70,206	0.003	0.015	0.091
Average	45.82	975,509	216,239	39,227	0.004	0.019	0.102

The problem of limited manpower in fisheries R&D, especially in institutions located in the provinces, deserves attention because of the rural nature of many fisheries activities. Researchers working in the countryside are more exposed to the actual problems in fisheries and are in a better position to correctly identify priority research areas for implementation. Thus, more of them should be recruited to enhance the capability of the sector to conduct hands-on and meaningful, not "ivory tower," research.

The Fisheries Code does not address the problem of limited R&D manpower in fisheries. The AFMA, on the other hand, stipulates the creation of a science fund to sustain career development. Both the Code and AFMA acknowledge that manpower problem is directly related to funding, and thus promise to increase the total R&D allotment, which, should they materialize, will go a long way in addressing the problem.

(d) Low level and poor maintenance of capital assets. While the data presented here relate only to funding and personnel resources, capital resources—in particular, buildings, facilities, and equipment—also help determine the success or failure of R&D. In fisheries, the capital resources for R&D have been wanting, more so in provincial institutions which receive smaller shares of the research budget. The problem of inadequate capital assets is worsened further by poor maintenance. There have been reports that proper maintenance is sometimes sacrificed by institutions to meet more immediate expenses,

such as salaries. In sites close to the sea, the faster deterioration of capital assets brought about by the presence of salt makes the problem of poor maintenance very serious.

Like the manpower problem, the inadequate and poor maintenance of capital assets is a function of funding. If the NARRDS institutions get higher allocations, they could purchase enough capital assets and spare money for maintenance. Again, the solution rests a lot on the increased allocations promised by the AFMA and Fisheries Code.

Manufacturing

Tracking down the developments in manufacturing R&D is difficult for lack of historical information, which effectively prevented the study team to assess it thoroughly. As mentioned in Section II, the breakdown of R&D expenditure that is available up until 1992 is entirely different from the sectoral breakdown in the Philippine Standard Industrial Classification (PSIC). As such, historical information is not consistent with what is available in the National Statistics Office data system. This is a major hurdle because R&D activities, which usually come in the form of investments and manpower availability, are analyzed against the indicators of sectoral output. For example, in the congruence rule discussed in Section III, optimal allocation of R&D budget should be proportional to the respective commodity value-added or value of production shares. While the latter is available from the NSO data, the former is not. However, David et al. (1999), after a tedious task of gathering and assembling information from almost all sectors in agriculture, were able to apply the analysis in a preliminary way. Based on the analysis, they were able to conclude that R&D allocation in agriculture is far from optimal.

However, the same analysis cannot apply to the manufacturing sector for lack of R&D data. What was done, instead, was to conduct a small survey (Macapanpan 1998 and Halos 1998) on selected industries in the manufacturing sector, and company interviews (Nolasco 1998) within those selected industries, including the Board of Investments (BOI). The discussion here is largely based on these papers.

The paper of Macapanpan (1998) focuses on the Philippines' private sector innovation activities. It was based on a survey of selected companies from five industry groups: (1) food processing; (2) textile and garments; (3) metals and metal fabrication; (4) chemicals; and (5) electronics and electrical machinery. The major conclusions of the study, in his words, are the following:

(a) Only big firms do engage themselves in innovation. These are industry leaders. Smaller firms may just be riding along, not following.
(b) Innovation activities are perceived by the firms to improve their competitiveness through improved quality, lower production costs, and enhanced marketing performance. Government standards and regulations and environmental concerns are not important drivers of innovation activities. As predicted by the relevant literature and studies, firms will formulate their technology strategy to support their overall business strategy.
(c) The steel industry has not acquired any significant new technology despite recommendations from various studies. The same is true for the textile industry, which has fallen behind in modernizing their equipment to remain competitive, quality- and cost-wise.
(d) Of the total respondent firms (more than 60), only seven firms employ Ph.Ds and only about 20 have master's degrees. A majority employ only college graduates, or lower, in their innovation activities, implying a very low level of innovation activity.
(e) Government research institutions rank very low as a source of innovation ideas. From interviews, the perception of the firms is that these research institutions lag even in monitoring technology developments in their respective fields. Internal R&D is not relied upon, except by the firms in the electronics and electrical industry. Ideas for innovation activities are usually sourced from the outside in the form of consultancy services; information on competitor activity generated by monitoring; purchase of technology, tangible and intangible; and the recruitment of manpower with the required skills.
(f) Financial constraints such as risk and rate of return, lack of financing, and taxation are the major hindrances to innovation. Technical constraints such as lack of information on new technologies, deficiency in external technical services, innovation costs, and uncertainty rank next as barriers to innovations. Others mentioned include difficulty in obtaining patents, low technological standards, lack of skilled personnel, and lack of opportunities for cooperation with other companies.
(g) Philippine firms are deficient in experience and organization to fully exploit technology as a source of competitive advantage. This situation is not helped by the lack of government assistance and support.

Government has been remiss in aligning the educational system with a globally and technologically competitive economy. The requisite technical and technological skills and knowledge are lacking in Philippine schools. Government research institutions have not diffused their findings to the private sector.

Based on a survey, Macapanpan (1998) was able to identify major gaps and stumbling blocks to the private sector's exploitation of the benefits of being technologically attuned and updated productive units. Based on interviews, Nolasco (1998) identified other gaps and major loopholes in the system:

(a) The overall system is loose and chaotic in the sense that different government agencies have different sets of priority sectors. Furthermore, some of the goals are unaligned. For example, the National Economic and Development Authority (NEDA), DTI, and BOI have varying sets of strategic sectors. The Department of Foreign Affairs and NEDA have conflicting interests with the BOI industry planners, especially in granting incentives. In particular, the Department of Energy is looking into the possibility of developing wind energy while the DOST is eyeing the solar energy.

(b) Government, with a limited budget for R&D, limits the amount of expenditure on R&D.

(c) Support facilities like testing centers, either government-run or subsidized; standardization institution; and support industries like casing and others are lacking or non-existent. Access to recent and state-of-the-art technologies is lacking due to poor databases.

(d) The system caters only to a handful of firms, usually the larger ones. Small and medium-scale firms have minimum access to the system.

(e) The staff assigned to the incentive promotion desk are not too familiar with the system of incentives. For example, some of them are not even aware of (1) the contents of the R&D incentives scheme called the list of Priority Areas (LOPA) and (2) that R&D incentives have existed for more than six years. Most of them would recall that R&D was integrated into the Incentive Promotion Program (IPP)-LOPA only in the past two years, when it has been there since early 1991.

(f) Government and private sector linkages are very weak. Thus, commercialization of developed technologies has not been well promoted.

As a result of these gaps and problems, only 11 companies, or a total of 13 projects, were granted incentives during the period 1991 to 1997.

Meanwhile, the results of Halos's (1998) survey of and interviews with private firms in the chemical industries, which produce chemical inputs into agriculture (such as fertilizer and pesticides), indicate that there has been a considerable reduction in R&D investments. The exceptions are in the sugar and coconut industries, where research funds have been mandated by government. In fact, the intensity of research activities by the private sector, except sugarcane and coconut, appears to have declined from the 1980s level. Information on R&D is scarce and hard to come by, but there are clear indications of this slowdown. For example, a number of multinational pesticide companies used to maintain research groups distinct from the marketing group, but only two continue to do so today. The regional research station of a multinational agrichemical firm has reduced not only the number (from five to three) but also the rank of its research staff (from two senior to two junior level).

Halos (1998) also observes that the government has adopted a policy of promoting local innovations and R&D activities. This is manifested in a major legislation, Republic Act 7459, which was signed into law in April 1992. The law provides multi-incentives package to encourage the development of inventions and facilitate their commercial application. For example, "the law provides for presidential awards, tax/duty exemptions, loan assistance and invention assistance development in prototyping, piloting, training, study tours, attendance to conferences/seminars, and laboratory tests and analyses. Various councils of the DOST provide counterpart R&D funds for private companies. Although respondents agreed that tax exemption for R&D equipment was conducive to their R&D initiatives, interviewees found the "procedures too cumbersome." Similarly, they found the "availment procedures and equity requirements for technology-commercialization loans cumbersome and too steep for small entrepreneurs." In fact, producers of organic fertilizers bewail the data required for Fertilizer and Pesticide Authority registration.

In general, Patalinghug (1998) argues that small and medium enterprises face several problems to acquire technology or to engage in R&D. Among these problems are (1) lack of funds; (2) insufficient information; (3) lack of skills in evaluating alternative technologies; (4) lack of technical know-how to shift to more advanced technologies; (5) inadequate mechanism for transfer of technologies; and (6) inertia of entrepreneurs because of no perceived or actual need for technology.

Education

The Philippines ranks low in terms of the number of R&D personnel. In 1992 the ratio of the number of scientists and engineers per million population was 152. From the supply side, this low level of S&T and R&D personnel is a result of the country's educational system that produces very few science and engineering graduates. While the number of students at the tertiary level is high in the Philippines, students taking up science and engineering courses are few. A big policy problem confronting the present educational system is educational "mismatch"—while there is a great demand for technical and engineering graduates by local industries, private tertiary schools continue to produce nontechnical graduates. One of the factors that explains this is that private schools prefer not to go into these technical related courses because of their high laboratory requirement, which is capital-intensive. Nontechnical courses, on the other hand, are less laboratory-intensive and therefore less capital-intensive.

The pool of R&D manpower is dominated by people with basic college degrees but generally have very limited advanced technical training. This in itself presents a big stumbling block because the new technologies available are already in advanced state and require special technical skills. Thus, the inadequate R&D manpower places the country in a very disadvantaged position because it does not have enough technical capability to adopt, through R&D, developed technologies in the market. In other words, with inadequate technological capability, the Philippines may find it difficult to catch up in terms of access to and mastery of the key emerging or leading-edge technologies. This, in turn, will negatively affect its future growth and international competitiveness.

A recent survey conducted by PIDS (Cororaton et al. 2000) on the R&D activities of government agencies and SUCs found that more than 30 percent of R&D personnel with Ph.D. degrees are in social sciences while only less than 5 percent are in engineering and technology (Figures 18 and 19). About 15 percent are in agriculture-related sectors.

This inadequate supply of R&D manpower can be traced back to the poor state of basic education in the country. This problem is rooted in the teacher training policy of the country and the public perception of the teaching profession (Magpantay 1995). He says, "To be able to teach in high schools, teachers must have a Bachelor of Science in Education (BSE) with a major and minor field. This degree program is short in content and heavy in methodology. In the end, teachers are knowledgeable in the standard way of teaching but do not know what to teach." Worse, he adds, because of the low regard for the teaching profession, it tends to attract only students who are generally regarded as uncreative and unimaginative. In any family, the intelligent among the children are encouraged to take up medicine, law, and, if mathematically inclined, engineering while the least academically capable are asked to take up BSE or BSEE (Bachelor of Science in Elementary Education) programs. "It is no wonder then," he says, "that the science and math education in the primary and secondary levels is in bad shape." Students are taught by the least academically inclined people who went through a program that emphasizes more on the form than on the content."

The poor S&T educational system results in low supply of skilled manpower (Sachs 1988). "In particular, there is a severe shortage of science teachers at the school level. The quality of science education at the college level is also poor. A substantial fraction of high school science teachers have no training in science and mathematics (but rather have degrees in education). High school math and physics curricula are badly in need of reform. A World Bank-funded engineering and science education project has provided scholarships for master's and doctoral training in science and engineering, but the scope of the project is limited. In general, there is a lack of capacity to do research, which will become particularly problematic in the future when forms will have greater demand for adopting and innovating existing technologies. Increasing the supply of science and technology education is probably the most crucial investment in science and technology that needs to be made *now*."

Health

The present study did not have the opportunity to include an analysis of the health sector R&D. However, the Center for Economic Policy Research (CEPR), through funding from the Department of Health (DOH), recently conducted an analysis of the funds flow into health research and development in the Philippines. Among the major objectives of the analysis were to: (a) trace the flow of health R&D resources; (b) assess the system for setting health R&D priorities; and (c) determine if health R&D funds match the priorities of the research agenda.

Some of the major insights derived from the CEPR-DOH findings, which are relevant to the R&D gaps analysis in this section are as follows:

(a) Of the P394 billion government budget for 1996, health resources accounted for P75 billion or 19 percent, while R&D resources had a meager share of P3 billion, or less than 1 percent.
(b) Resources for health R&D amounted to P421 million, which was equivalent to 17 percent of R&D resources and 1 percent of health resources. The latter is below 2 percent of the national health expenditures, the proportion recommended by the Commission for Health Research and Development (CHRD) for health R&D.

Other Important Gaps

In his study of the long history of S&T and R&D in the Philippines, Eclar (1991) says its beginnings can be traced back to the American colonial period. Significant changes have since transpired, including those in the structure, system, leadership, and administration. Recently, programs and plans were launched like the Science and Technology Master Plan (STMP) in 1990 and the Science and Technology Agenda for National Development (STAND) in 1993. However, no successes can be cited yet, only failures (Patalinghug 1998). For example, the S&T sector faces the following major problems: (a) underutilization of S&T for development, as reflected in the low quality and productivity of the production sector and heavy dependence on imports; (b) underinvestment in S&T developments in terms of manpower training, technological services, R&D facilities, and financial resources; (c) weak linkages between technology generation, adaptation, and utilization; and (d) slow commercialization of technologies because of a very weak delivery system, which in turn is the result of weak linkages especially between government research institutes and end-users.

Patalinghug (1998) adds that "there has been a general failure to use technology to gain competitive advantage. Resource-based exports (e.g., timber, copper) are basically in raw material or unprocessed form. Traditional agricultural exports (coconut, sugar, and banana) are also exported without infusing technology-based processing in the value-added chain. The shift from primary exports (coconut, sugar) to manufactured exports (garments, electronics) simply reflects the changing factor composition of exports (that is, from being resource-intensive to labor-intensive). The shift from labor-intensive to skills- or technology-intensive manufactured exports has not yet occurred."

Institutional weaknesses. A number of institutional gaps clearly exist. Some of these include:

(a) *Failure in execution and implementation.* Patalinghug (1998) compares the S&T system in the Philippines and in South Korea. He says, "Basically, in form and intent, the Philippine S&T development plan is comparable to that of Korea. Thus, the basic weakness of the Philippine experience is in its execution and implementation. Although there are some weaknesses in the plan formulation in the Philippines, because the planning exercise is detached from the budgeting exercise, the more decisive factor is the weakness and organization arrangement to ensure timely and correct implementation."
The existing intragovernment coordination system suffers from major flaws. In particular, the system of performance monitoring and evaluation is lacking or defective. "In fact, the government's Investment Coordination Committee (ICC), which is chaired by NEDA, has been lengthily reviewing projects intended to address the adverse effect of the financial crisis. But based on the ICC's inefficiency in evaluating development projects, these projects are more likely to be approved when the economic conditions they are supposed to address are no longer there. The ideal institutional arrangement is definitely to establish a coordination mechanism between the S&T plan, the budget plan, and the Medium-Term Philippine Development Plan (MTPDP). Unfortunately, the prospects of establishing this linkage in the Philippine bureaucracy, in the short run, are not promising."

(b) *Other causes of institutional failure.* Some argue that the Korean government has the political will and the consensus among its stakeholders to give top priority to S&T development in the allocation of resources. Magpantay (1995), on the other hand, claims that the DOST is a highly inefficient structure largely because it "is doing too many S&T activities, charged with too many functions, operating in a bureaucracy with too many constraints, and given too little support." This is manifested in the DOST-STMP 15 leading edges and STAND 22 R&D priority areas. These areas are all-inclusive and practically cover all industries and all technologies with too little financial resources. This is a clear example of poor planning and poor budgeting. Patalinghug (1998) concludes that "the most reasonable conclusion that can be made is that both STMP and STAND cannot be implemented. Their defects arose from the following factors: (1) budgeting and planning were not harmonized in the drafting of the S&T plan;

(2) the capabilities of implementing agencies were ignored; (3) solid support from various stakeholders was lacking; and therefore (4) resources for S&T development were insufficient. By any standards, the amount actually used for R&D in the DOST budget is absolutely too little."

(c) *Failure of industrial policy.* There are renewed attempts to formulate industrial policy (Patalinghug 1998). This is a reiteration of the vital role of industrial progress to sustain future economic growth in the country. "However, ad hoc or de facto industrial policies (as formulated by the Export Development Council, Industry Development Council, and Small and Medium Enterprises Development Council) have not stressed the need for active promotion of technology to build a strong foundation for industrialization." The STAND has identified what is called "export winners" or "industry/product winners." Patalinghug argues that identifying these winners without technology is like running a vehicle without an engine.

There are at least 12 priority sectors that have been implicitly identified in the recent pole-vaulting strategy. However, the technologies in support of these "must-do" programs have yet to be identified.

IV

Policy Lessons for the Philippines

This paper lays out at the outset that: (a) a productivity-based growth is more sustainable in the long run than a factor accumulation-based growth; (b) a growth strategy that is consistent with productivity-based growth is technological innovation-based; and (c) in developing countries where institutional rigidities as well as market imperfections are prevalent, technological innovation-based growth strategy is extremely difficult to implement. The impressive growth of the Japanese economy after World War II was generally a productivity-based growth achieved through a technological innovation-based strategy. Technological innovation, as discussed in Section I, involves a dynamic process. At each step of the process, economic growth improves, as Japan has shown. The experience of Japan therefore provides useful policy lessons for developing countries like the Philippines, which are struggling to grow. It was against this backdrop that the paper was conceptualized.

The paper attempted to review the growth process in Japan after WWII. It then analyzed the initial conditions, the economic environment in which the economy was operating, the goals and strategies pursued, the institutions established, the economic policies implemented, the programs developed, the role of government in the entire process, and the involvement of the private sector. Since the main objective was to draw policy lessons for the Philippines, the paper analyzed in great detail the local S&T experiences for purposes of comparison.

The analysis of the experience of Japan yielded the following lessons: (1) accumulation of technological experience is extremely important, which, in the case of Japan, was started years before World War II broke out through its prewar industrialization policies; (2) key institutions, which proved to be very crucial in the process, were established (like the Science and Technology Agency, research institutions, labor unions, patent office, etc.); (3) the industrial strategy pursued was seen as managing the process of technological change to achieve a dynamic industrialization (as was quite evident in the phasing in and phasing out of Japan's priority industries and the rapid growth of R&D during the period when the technological gap with developed countries in Europe and America was closing); (4) importation, adaptation, assimilation of foreign technology are important; (5) incentives and subsidies are vital to promoting private participation, which in a neoclassical sense is inefficient but in reality is effective if granted in a competitive manner through a set of criteria laid out by the government; (6) manpower development can be achieved through basic and formal education, vocational training, and company-sponsored skills-enhancing programs; (7) sound macroeconomic management and stable economy are extremely essential to private participation; (8) strong leadership ensures political stability; and (9) shared development can be attained through the rapid expansion of the middle class.

While Section II discusses the foregoing in detail, it is important to elaborate further two important issues that are particularly relevant to the Philippines: (a) industrial strategy; and (b) proper institutional arrangements.

The current debate in the economic literature puts the issue of industrial strategy that is consistent with the arguments of Hirshman (1958) on the sidelines. In fact, the issue of the day is globalization through "making prices right." While this may be justified by the failures of some countries which adopted import substitution policies through targeting, like the Philippines, Brazil, and India, to name a few, "making prices totally right" may be unrealistic, especially if technological change is at the heart of the growth strategy. The market of technology is highly imperfect, while the economic environment within which these developing countries are operating is adverse to technology-based institutions because of the factors outlined in Section I.

The case in point is the Philippines, which has been exerting a lot of effort in implementing economic reforms that are consistent with globalization. While the prevailing set of economic reforms[15] is extremely important to overhaul the inefficient production structure of the economy, it lacks focus and provides no clear direction for technological innovation. The recently adopted S&T plan of the government lists down 23 industries as priority areas. They are simply too many, since the production lines of these industries are totally unrelated. The case of Japan, and to a great extent South Korea, is very clear: the technological innovation strategy was attuned, synchronized and con-

[15] Economic reforms include trade reforms, financial reforms, fiscal reforms, exchange rate reforms, invetment reforms and other market reforms through privatization and liberalization.

sistent with the overall industrial strategy. This is a very important lesson for the Philippines during this period of economic reform. The process of technological innovation cannot start and gain momentum unless some kind of an industrial strategy is adopted. Activities in technology area are simply too risky and to a great extent capital-intensive. Unless clear directions are set, the private sector would be hesitant to participate no matter how attractive government incentives are. In the Philippines, incentives have been made available to R&D-related activities since the early 1990s, with very few takers.

The second issue involves institutional arrangements. A review of S&T experience in the Philippines provides some clue that key ingredients for a technology-based growth strategy may already be present. While they may not be on a par with Japan, a relatively long S&T experience, the institutions, the policies, and, to a limited extent, the manpower are present.

However, there is an institutional failure because of very weak institutional arrangements. Planning and budgeting exercises are uncoordinated, resulting in very poor performance and project failures. Focus is also lacking, especially in attracting the private sector, through, for example, the commercialization of some developed technologies.

The lessons discussed may have some important implications to the policy formulation exercises in the Philippines, but they are general. Equally relevant are specific policy recommendations, which must also be considered. These include improvements in (1) R&D investments; (2) R&D manpower; (3) incentive system; (4) institutional arrangements and S&T coordination mechanism; (5) R&D delivery system; and (6) statistical information and accounting system.

R&D Investments

There are convincing pieces of evidence showing significant underinvestment in R&D in the Philippines. This is true at the national as well as sectoral levels. For example, Cororaton (1999) estimates a gap in R&D expenditure of 0.5778 percent of GNP at the national level. David et al. (1999) also observe significant underinvestment in agriculture. Israel (1999) also found the same thing in the fisheries sector. Underinvestment in R&D is also very apparent in the private, manufacturing sector, as noted by Macapanpan (1998) and Halos (1998). The recently completed study on the flow of R&D funds in the health sector by CEPR-DOH (1998) also found substantial underinvestment in R&D.

There is also an equally convincing set of facts indicating high rates of return on R&D investments. This being the case, underinvestment in R&D and high rates of return may imply high opportunity cost. While it is extremely difficult to compute opportunity cost because of lack of information, it is nonetheless evident in other indicators like productivity. Productivity performance in the Philippines has been very poor. In fact, this has been the major factor behind its unsustainable growth path. In principle, R&D activities lead to innovation, to technological progress, and finally to economic growth and prosperity. A huge body of literature supports this.

The biggest issue at hand is: Who would fill in the gap? Rough calculations indicate that there is a gap of about P14 billion at current prices. For sure, the government sector cannot fill in this gap because of financial constraints. Furthermore, the government has other equally important concerns such as basic infrastructure and other social sector needs. Naturally, it has to be the private sector (either local or foreign) that should fill in the gap. However, the private sector will only respond to appropriate incentives. Further discussion on this is given later in the section.

Part of the gap can be attributed to the misallocation of allocation of resources. In fact, in agriculture, David et al. (1999) argue that misallocation of public sector research funding is as important as underinvestment. They cite specific examples. Using the congruence rule, they have found that "relatively greater research budgets are provided for minor commodities such as cotton, silk, and carabao, and too little for major ones such as corn, coconut, fisheries, and others. Furthermore, Mindanao regions are relatively neglected in terms of the research budgets of the DA and SUCs compared to the regions in Luzon and, to a lesser extent, to those in the Visayas. While congruency does not strictly coincide with optimal research resource allocation, the differences in research intensity ratios observed among commodities and across regions cannot be explained by possible differences in cost of research (probability of research success, etc.), future market potential, or equity considerations."

Another manifestation of misallocation of resources lies in the allocation of budgetary resources by type of expenditure. David et al. (1999) observe that "too little resources are available to perform research activities and to properly maintain the physical facilities, after the salaries of personnel have been paid. The average share of personal services to direct budgetary outlays is close to 60 percent and goes as high as 70 to 80 percent in many cases. Consequently, either the research manpower is underutilized or the research agenda is driven by donors' priorities."

Due to lack of information arising out of extremely poor databases on R&D activities, misallocation of research resources in other sectors like the manufacturing cannot be conducted. However, given the nature and extent of problems in the R&D system in the Philippines, the issues affecting agriculture seem generic to all sectors of the economy.

Aside from underinvestment and misallocation of research resources, there is another big problem of untimely release of funds to institutions, programs, and projects. In fact, this is true not only in R&D but also in other activities that are dependent upon government funding and support. Israel (1999) mentions this as one of the major concerns in the fisheries sector. "In fisheries, it is acute because of the importance that time and season play in the conduct of activities. Although there are no data which can be used to validate this, research activities are reported to be cancelled or haphazardly conducted because of the delay in the release of funds," he says. Patalinghug (1998) has recommended that DBM be involved with DOST in the S&T and R&D planning formulation stage so that the needed resources are made available to implement such plans without delay. This issue will also be addressed later in the discussion on institutional arrangement.

R&D Manpower

The issues surrounding R&D manpower are equally problematic as, if not more problematic than, the foregoing. This is because the problems in this area can be traced back to the educational system, which is not only difficult to reform but would also take long before reforms can be successfully implemented. Lag time could take about 15 to 20 years—the required time to properly educate and equip the children with the necessary skills and talents before they can enter the workforce.

Cororaton (1998) estimates that the gap in the R&D manpower is about 197 scientists and engineers per million population. In agriculture, David et al. (1998) observe that the gap in R&D manpower is not so much in terms of number as in the relatively low level of scientific qualification of agriculture researchers. They warned that there is an urgent need to strengthen manpower capability in DA and DENR research agencies. Israel (1999) also observes a severe shortage of qualified personnel in the fisheries sector. The same is true in the private manufacturing sector (Macapanpan 1998 and Halos 1998). In fact, a PIDS survey (Cororaton et al. 2000) found that the majority of R&D personnel have only basic college degrees. A small percentage has doctoral degrees, which are mostly in social sciences. A very tiny percentage of Ph.D. holders are in engineering and technology.

While the Philippine educational system produces one of the biggest numbers of college graduates compared to other countries, it generates one of the smallest numbers of graduates with science and engineering skills (Cororaton 1999). There are a host of factors behind this. One of these is the educational "mismatch" at the tertiary level—while there is a great demand for technical and engineering-related graduates by local industries, private tertiary schools continue to produce nontechnical graduates. One of the factors that explains this is that private schools, which dominate the tertiary level, prefer not to offer technical courses because of their high laboratory requirement, which is capital-intensive. Non-technical courses are less laboratory-intensive and therefore less capital-intensive.

At the secondary or high school level, a substantial fraction of high school science teachers have no formal training in science and mathematics (Magpantay 1995 and Sachs et al. 1998), only degrees in education. There is, therefore, an urgent need to reform high school math and physics curricula. This problem also holds true at the primary level.

In almost all sectors, the lack of adequate manpower surfaces out. To sustain a long-term growth, the country urgently needs to reform the science and technology education system. In fact, investment in science and technology education is the most crucial investment that can be made now (Sachs et al. 1998). Otherwise, it would be too late since returns to this investment have usually very long gestation period or time lag.

Patalinghug (1998) offers specific recommendations: (1) Strengthen S&T education at the elementary and secondary levels. The quantity and quality of elementary and secondary teachers of science and mathematics must be addressed in the MTPDP: 1999-2004; (2) Implement a strong science and engineering program to support an expansion of science and engineering enrollment at the tertiary level. Related to this is the need to expand the facilities of science and engineering institutions and encourage the hiring of qualified faculty from abroad; (3) Intensify the effective recruitment of Filipino scientists and engineers working abroad by designing an incentive program that matches the cost of the Education and Science Education Project;[16] and (4) Expand the Philippine Science High School system.

[16] South Korea did this in the early 1960s with great success.

Incentive System

People, especially the private sector, respond to incentives. Incentives that are deemed particularly important to R&D activities include: (1) stable economy; (2) institutional protection; (3) access to capital and financing, especially by the SMEs; (4) good R&D infrastructure; and (5) fiscal incentives.

Normally, there are high risks involved in R&D activities, particularly uncertainties in the outcome of an R&D undertaking. Favorable results of an R&D undertaking will not emerge 100 percent or with certainty. In fact, the possibility of failure is great. Furthermore, there is the high incidence of spillover or externality that is hard to appropriate. In this regard, government intervention is critically needed.

Ample literature and empirical evidence support the fact that a stable macroeconomy helps encourage productivity-enhancing activities like R&D, especially by the private sector. Therefore, conducive macroeconomy is one of the major incentives that can be offered to private investors. The role of the government is particularly important in managing the economy so that inflation rate, interest rates, risk premiums and etc. are kept at the minimum.

There are also clear indications from the literature that institutional protection is critically needed. Institutional protection comes in the form of patents and intellectual property rights. These issues have not been addressed in detail in the present paper, but certainly there are problem areas that need to be ironed out here. To be sure, there are indications that the number of patents granted have declined through time.

Macapanpan (1998), Halos (1998) and Nolasco (1998) have observed through company interviews and surveys that one of the major constraints preventing some of the firms, especially the SMEs, from conducting and pursuing R&D activities and plans is the lack of access to cheap capital and financing. The cost of capital in the Philippines is traditionally high because of distortions in the financial system.

R&D and S&T infrastructure is also one crucial incentive that could attract the private sector to pursue technology-related activities. Appropriate infrastructure could come in the form of (1) a strengthened educational system which can produce a workforce with adequate R&D capabilities, as well as reliable and updated databases and information system; (2) wide and easy-to-access network on technology developments; (3) a mechanism to attract Filipino scientists and engineers to come home; and (4) a mechanism whereby research results and output of research institutions and universities can be delivered to the end-users, among others.

Macapanpan (1998), Halos (1998) and Nolasco (1998) also note that fiscal incentives are important in attracting the private sector to go into R&D activities. Cororaton (1999) lists down some of the major fiscal incentives in the Philippines, and finds that these were generally similar to the ones offered in other countries. However, fiscal incentives have to be handled properly, as these would have significant budgetary implications. Furthermore, although fiscal incentives are important, results would indicate that there are major inefficiencies in the granting of incentives by the BOI. For example, Nolasco (1998) notes that from 1991 to 1997, only 11 companies or a total of 13 projects, received incentives. Patalinghug (1998) therefore suggests the need to "design an incentive package, with strict qualifying requirements on what constitutes R&D activities, to encourage private sector R&D. An external peer review committee is recommended to act as the screening mechanism." The granting of fiscal incentives may be conducted on a competitive basis through a set of performance criteria that may be defined by the government.

Israel (1999) discusses other important incentive issues that need attention. In particular, it was noted that in most cases, researchers conducting research using the funds from their own agencies are accorded minimal financial incentives. Remunerations from projects funded by other government sources have been low. As a result, many researchers tend to do odd jobs not related to research, or consulting work for private and international organizations. The results of the PIDS survey on R&D manpower, particularly those involving R&D personnel with Ph.D. degrees, point to this trend (Cororaton et al. 2000).

The Magna Carta for the Government Science and Technology Personnel (Republic Act 8439) was recently passed to address the problem of low incentives, but it remains to be seen whether this will solve the problem. In particular, the law allows for the provision of honoraria, share of royalties, hazard allowance and other benefits to science and technology workers.

Patalinghug (1998) offers additional recommendations that can improve the S&T incentives. These include (1) allocation of an annual funding for the implementation of the Scientific Career System (SCS). However, entry into SCS should be limited by giving top priority to the target groups, natural scientists and engineers; and (2) the implementation of a competitive bidding, strictly based on merit, in the awarding of research projects by pooling a major portion of the country's R&D resources to be administered by an agency similar to the National Science Foundation (NSF).

Institutional Arrangement and S&T Coordination Mechanism

From all indications, the entire R&D system, as well as the general S&T system, is in a state of disarray because of lack of leadership, direction, and coordination. There are systems, as well as administrative failures, that result in wrong implementation of the plans, projects, and programs. There are also policy failures due to the lack of focus on technology in the overall development strategy. To address these problems, Patalinghug (1998) recommends the following reforms: (a) DBM must be involved with DOST in the S&T plan formulation stage so that S&T resources are available to implement the plan; (b) STCC must draft a Medium-Term Science and Technology Development Plan a year before the drafting by NEDA of the next MTPDP. An inter-agency joint committee must integrate the Medium Term Science and Technology Development Plan into the MTPDP by decomposing them into an annual budget plan, annual S&T plan, and annual economic plan, and then harmonizing its goals, projects, programs, strategies, resource requirements, and timetables; (c) DOST must establish a project and program monitoring unit staffed by at most three persons whose main job is to coordinate the selection, through competitive bidding, of external evaluators and reviewers for the different projects and programs implemented under the S & T plan; and (d) an STCC chaired by the President must meet at least once every three months to address current problems that pose obstacles to the implementation of the S&T plan. An MOT unit attached to DOST (just like PIDS is attached to NEDA) will act as the technical secretariat of STCC under the direct supervision of the DOST Secretary.

R&D Delivery System

Eclar (1991) notes the very slow commercialization of technologies in the Philippines. This is largely due to the very weak delivery system and poor linkages of S&T organizations with industry and other government agencies. To improve the linkages Patalinghug (1998) has a number of recommendations:

(1) Reorganize the government-supported R & D institutes into a new corporate structure that gives them flexibility as well as responsibility to gradually develop its fiscal autonomy.

(2) Establish funding schemes through DOST and the Commission on Higher Education (CHED) to support a consortium or network of schools to maximize the use of resources.

(3) Focus funding support for developing core competence in targeted regional universities. For instance, the University of San Carlos can specialize in chemistry and chemical engineering; MSU-IIT in mechanical engineering; and Xavier University in biochemistry and agricultural engineering.
(4) Promote S&T culture by giving presidential awards to outstanding science and engineering projects selected through a nationwide competitive search. Encourage science-oriented TV and radio programs, fairs, plant tours, and apprenticeships.
(5) Install a scanning and monitoring scheme of world technological trends for dissemination to local industries, research institutes, and universities.

Eclar (1991) conducted a comprehensive analysis of factors affecting commercialization of technologies. Her study identified user participation. Successful commercialization is promoted when a user with a specific need has been identified at the start of the project. The user generally maintains an interest in the progress of the research and takes on the commercialization of the results at the completion of the research project to meet his previously identified need. This is reinforced when the user's interest in the project is translated into support or cost sharing.

Another important factor is pilot testing. Demonstration of the technical viability of the technology in a semi-commercial scale helps convince an industry user to start off the commercialization process. Commercial success is ensured when the user himself has provided material inputs to the pilot test.

Statistical Information and Accounting System

Good and accurate analysis of R&D opportunities is one of the major factors that would help encourage private, as well as public, investment into R&D and S&T-related activities. This is because, normally, there are high risks involved in R&D investments (particularly the uncertainty in the outcome of an R&D undertaking), coupled with the high incidence of spillover or externality that is hard to appropriate. These uncertainties and other market failures can be minimized if the statistical information and accounting system is well established. A good information system leads to good analysis of the structure and nature of R&D activities. If there are significant market failures, with good analysis, then appropriate and correct policy measures can easily be formulated to correct these market kinks. However, the present statistical information and accounting system is extremely poor. It generates very inaccurate information on the variables of particular interest in policy. This assessment is based on the recent R&D survey conducted by PIDS (Cororaton et al. 2000). Thus, there is an urgent need to overhaul the statistical information and accounting system on R&D and S&T activities. The first major step involves making the survey questionnaire consistent with the accounting system of the institutions so that information can flow immediately from the information system of the respective institutions into the R&D database. The next major step involves reconciling the variables in the questionnaire consistent with the NSO-PSIC sectoral breakdown. The third recommendation is to institutionalize the data system in NSO, because of its expertise in gathering information and its extensive nationwide network. By doing so, regular information is generated and regular monitoring and analysis are conducted.

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